

# ATTENTIONAL FOCUS AFFECTS EMG ACTIVITY AND MOTOR PERFORMANCE DURING SIT-TO-STAND IN ADULTS AND THE ELDERLY

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## Abstract

Even though the benefits of external focus appear to be consistent on movement effectiveness and efficiency, few studies have examined the effects of changing attentional focus on sit-to-stand. The purpose of this study was to investigate the effect of attentional focus and age-related differences on the feature of muscle activity and self-reported response time during sit-to-stand under different conditions of attentional focus. Twenty-two young adults and 18 elderly people were recruited in this study. Electrodes were attached to the rectus femoris, biceps femoris, tibialis anterior, and the medial gastrocnemius muscles to monitor electromyography features during standing up. The %maximal voluntary contraction (%MVC), onset, and duration of muscle activities were calculated. A self-reported response time was also recorded. First, the patterns of muscle activities were in compliance with all conditions of attentional focus, including the %MVC, onset, and duration of muscle activation in both age groups. Secondly, the self-reported response times of the external focus (EF) and internal focus (IF) were longer than that of the no attentional focus (no AF) in both age groups. Finally, both age groups showed that the sit-to-stand with somatosensory-internal focus (SIF) generated longer self-reported response times than the EF, whereas the sit-to-stand with muscular-internal focus (MIF) was not different from the EF. In contrast, there was an age-related difference in the duration of muscle contraction. The qualities of the sit-to-stand under different attentional focus, in terms of force generation, onset, and duration of muscle contraction were quite similar in both age groups.

**Keywords:** Electromyography features, focus of attention, self-reported response time, standing up

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## Introduction

The nature of sit-to-stand (STS) movement is dynamic and destabilized because of a rapid change of body positions from the sitting posture, which is actually stable and with a wide support, to the standing posture with a narrow support between the feet and with a higher center of mass that reduces body stability (Roebroek *et al.*, 1994; Khemlani *et al.*, 1999; Burnfield *et al.*, 2012). The STS movement is divided into 2 phases, pre-extension and extension. The pre-extension phase starts from leaning the trunk forward, raising the buttocks, and moving the knee forward in order to generate upper body momentum. For the extension phase, the hips, the legs, and the trunk are extended. Weight is transferred down to the feet. The significant muscles activated during the sit-to-stand movement include the gluteus maximus, quadriceps, hamstrings, gastrosoleus, and tibialis anterior (Khemlani *et al.*, 1999; Carr and Shepherd, 2003).

A clear understanding of the features of the STS movements requires a basic knowledge of the determinants that influence how the movement is performed. Generally, the determinants are often divided into 2 domains- constraint-related and participant-related. There are constraint-related determinants that have been already studied in order to gain insight into the influence of the determinants on STS movements, such as the height of a chair and the foot position (Roebroek *et al.*, 1994; Raina *et al.*, 2005). Beside these factors, it is generally known that attention to movement is able to modulate motor responses. For instance, directing attention away from cued movements is able to shorten the reaction time (Wulf *et al.*, 2001) and increase the frequency of movement adjustments (McNevin *et al.*, 2003). Surprisingly, little experimental research has addressed the influence of attending to movement on the performance of STS movements. Previous research has not directly emphasized the effect of the focus of attention on STS performance. Usually, only verbal instructions are provided to keep the movement correct

and inhibit habitual postural adjustments (Stevens *et al.*, 1989; Yamada and Demura, 2005; Gillette and Stevermer, 2012; Sato *et al.*, 2012). It can be seen from previous research that instructions were not precisely detailed and oriented towards directing attention to the STS movement. Therefore, it is worth knowing how beneficial focus instructions are to the performance of STS movements before utilizing them in enhancing the STS skill in the future.

Focus of attention is a common variable used in either motor learning research or rehabilitation in order to improve motor performance and learning. Based on work in exercise science, 2 types of attentional focus are of particular interest - the external focus (EF; directed to the effects of movement in the environment) and internal focus (IF; directed to the movement itself). In previous studies of motor performance, it has been found that the EF results in a greater advantage when compared to the IF. Even though the benefits of the EF during the performance and learning appear to be clear and consistent, generalizable across motor activities and population (Fasoli *et al.*, 2002; Wulf and Su, 2007; Wulf *et al.*, 2009), and with measure outcomes reflecting movement effectiveness (e.g. accuracy and balance) (Wulf and Prinz, 2001; Wulf *et al.*, 2001; McNevin *et al.*, 2003; Wulf *et al.*, 2004; Jackson and Holmes, 2011) and movement efficiency (e.g. electromyography (EMG), force production and speed) (Marchant *et al.*, 2009; Lohse *et al.*, 2010; Wulf *et al.*, 2010; Marchant and Greig, 2017), few studies have investigated the effects of the focus of attention on the standing up movement.

According to the literature review, Srisupornkornkool (2014) studied the effects of attentional focus on the sit-to-stand performance in young adults and elderly who were instructed to focus their attention on a marker on a wall (visual-external focus; EF), the loading on the thigh (muscular-internal focus; MIF), and to the pressure transferred to the feet (somatosensory-internal focus; SIF)

during the STS movement. The results found that the young participants' movement was faster, and their stability greater, under the EF. The older participants' speed did not differ as a function of attentional focus, but their stability during postural transition was greater under the MIF. However, the study concentrated on movement outcome, not on the quality of movement, especially muscle activity during the STS movement under the focus of attention. This study therefore aimed to explore the effects of attentional focus on leg muscles activity during the standing up movement. We hypothesized that the sit-to-stand movement with the EF would increase movement efficiency, like other relevant previous studies. EMG was used for monitoring muscle activity of the rectus femoris, biceps femoris, tibialis anterior, and medial gastrocnemius (Millington *et al.*, 1992; Goulart and Valls-Solé, 1999) during the STS movement under the EF and IF.

It would be interesting to examine how differential effects of attentional focus interact with age-related differences. Older people are known to accrue deficits in motor planning (Ketcham and Stelmach, 2002), control, and execution that increase reliance on visual information to guide movements (Haaland *et al.*, 1993) as proprioceptive control deteriorates with decreasing muscular strength (Butler *et al.*, 2008). This suggests that young and older participants may respond differently to changes in attentional focus from internal (proprioceptive) to external (visual) focus aspects of coordination. However, the direction of any such difference is unclear. Older people may benefit from external (visual) focus, or from focusing on proprioceptive information (if deliberately directing attention counteracts the deficits they have in utilizing this type of information).

The present study aims to investigate the effect of attentional focus on the feature of muscle activity during the STS movement. Also, a particular interest in the present study was age-related differences in the feature of muscle activity during the STS movement under attentional focus conditions.

## Materials and Methods

### Study Design

This research was an experimental design. The study was designed to monitor EMG and the self-reported response time during the STS movement under different attentional focuses. Assessors were not involved in this study and the participants were blind to the outcome measures, as no results were disclosed or discussed during the study. The study was ethically approved by the Ethics Committee (HSSREC) of Naresuan University before it commenced. Potential participants were given advanced information regarding general task requirements and the opportunity to seek clarification before choosing to participate. All participants provided written informed consent before taking part in the study.

### Participants

Twenty-two young adults (20-29 yrs) and eighteen elderly people (60-69 yrs) were recruited for this study. Based on a previous study (Burnfield *et al.*, 2012), a formula for comparing 2 means (a statistical power = 80%, a confidence level = 95%, the variance = 5, and the mean difference = 3) was used to determine the sample size. All participants were screened to ensure that they had no impairment of standing up multiple times per session. The screening also ensured that they had a normal body mass index (BMI; normal = 18.5-24.5 kg/m<sup>2</sup>), no mental disorders, and no significant medical history or current problems affecting balance or everyday motor function. Participants with a Mini-Mental State Examination (MMSE) score below the cut-off score which was adjusted for education (Institute of Geriatric Medicine, Department of Medical Services, Ministry of Public Health), or a habitual physical activity score over 6 (Baecke *et al.*, 1982) were excluded. Details of the participants are shown in Table 1.

### Experimental Procedures

The experiment was conducted in a quiet room within a laboratory suite at the Allied Health Science Faculty, Naresuan University.

**Table 1. Physical characteristics**

|                                                        | Young adults<br>(N = 22)<br>Median [Q1, 3] | Older adults<br>(N = 18)<br>Median [Q1, 3] |
|--------------------------------------------------------|--------------------------------------------|--------------------------------------------|
| Gender (M : F)                                         | 11 : 11                                    | 8 : 10                                     |
| Age (years)                                            | 23.00<br>[21.75, 25.00]                    | 63.50<br>[61.00, 67.00]                    |
| Body weight (kg)                                       | 56.05<br>[51.88, 61.75]                    | 57.25<br>[48.73, 63.30]                    |
| Height (cm)                                            | 165.00<br>[153.38, 171.88]                 | 157.00<br>[151.25, 164.50]                 |
| BMI (18.5-24.5 kg/m <sup>2</sup> )                     | 21.70<br>[19.35, 22.50]                    | 24.00<br>[20.48, 24.53]                    |
| MMSE score                                             | 29.50<br>[28.00, 30.00]                    | 24.50<br>[22.00, 26.00]                    |
| Habitual physical activity                             | 5.75<br>[5.72, 5.88]                       | 5.73<br>[5.09, 8.63]                       |
| Leg dominance<br>Right : Left (number of participants) | 22 : 0                                     | 18 : 0                                     |

Q: interquartile; M = male; F = female; BMI = body mass index; MMSE = mini-mental state examination.

Participants were asked to take a seat on a vertically adjustable chair set to the height of their lower legs without arm supports. The participants' feet were placed on the floor with their heels approximately 10 cm apart. The participants' ankles were positioned with  $\sim 10^\circ$  of dorsiflexion and knees with  $\sim 100$ - $105^\circ$  of flexion (Cheng *et al.*, 1998). EMG electrodes were attached to the participants' rectus femoris, biceps femoris, tibialis anterior, and medial gastrocnemius muscles of their right legs to measure the EMG activity.

Each participant performed the STS movements with natural speed under 4 focus conditions - no focus (no AF), visual-external (EF; focus on a fixation point on the wall), muscular-internal (MIF; focus on extension of the thigh), and somatosensory-internal (SIF; focus on the load on their feet). The order in which the participants encountered the focus conditions was counterbalanced among the 4 focus conditions in order to minimize the learning effects in the subsequent session. Participants were simply randomly assigned to 6 counterbalanced orders; 1) no AF-EF-MIF-SIF, 2) no AF-EF-SIF-MIF, 3) no AF-MIF-EF-SIF, 4) no AF-MIF-SIF-EF, 5) no AF-SIF-EF-MIF, and 6) no AF-SIF-MIF-EF. In each focus condition, the participants first performed 2 practice trials followed by the 3 recorded trials, with 1-5 min of rest in between or however long was needed before they exhibited no sign of fatigue. In each trial, the participant awaited an instruction. The participant heard the words

"Ready and Go", and immediately following this signal they had to perform the STS movement. As soon as they felt that they had completed the movement and were standing steadily, they said the word "Finish" out loud to indicate the end of the movement. The self-reported response time was recorded from starting to standing steadily with a stopwatch. Then, the participants were asked to sit down, relax, and prepare for the next trial.

In the EF, the instruction to the participants was to stand at their natural speed while keeping their eyes on the fixation target, and focusing on the way their viewpoint position changed relative to the fixation point. The fixation target was always positioned at the participants' standing eye-height. The distance between the seat and fixation target was about 1.3 m. In the MIF, the participants were told, "As you stand up, focus your attention on how your thigh are straight", and in the SIF, they were told to focus their attention on how the pressure of their body weight felt under their feet.

### Electromyography

EMG electrodes with a 0.5 cm active surface were attached to the participants' rectus femoris, biceps femoris, tibialis anterior, and medial gastrocnemius muscles of the right leg. Prior to electrode placement, the skin was first dry-shaved and then cleaned with an alcohol swab to decrease impedance. Two electrodes were placed 2 cm apart on each muscle belly

in line with the fiber direction (Cram *et al.*, 1998). A ground electrode was placed on the participant's right knee over the lateral epicondyle. Before starting the experiment, the intra-rater reliability for monitoring EMG signals was determined using an intraclass correlation coefficient model 3, k. The result showed the highest level of reliability. To avoid inter-experimenter variations, the same experimenter applied the electrode to all participants.

The EMG signals were recorded at 1500 Hz using a 4-channel wireless surface EMG system (MyoMuscle MR3 3.8.6, Noraxon, AZ, USA). The EMG data of each muscle's maximum voluntary contraction (MVC) were recorded and used for normalization processes. The EMG data from the MVC test were filtered using a smoothing algorithm with a mean window of 50 ms for each muscle during the static end position. The MVC was measured in microvolts ( $\mu\text{V}$ ). The starting position for testing the MVC followed Cram *et al.* (1998). The MVC of each muscle was tested 3 times with a running period of 30 sec and 90 sec rest in between, and participants were asked to rest until they exhibited no sign of fatigue before the testing session of each muscle.

Next, the EMG signals of the 4 muscles of the dominant leg were recorded during the STS under the 4 focus conditions. The average amplitude of each condition's signal was presented as a percentage of the maximum voluntary contraction (%MVC) for that muscle. The %MVC was calculated by the following equation:

$$\%MVC = \frac{\text{Test EMG} - \text{Resting EMG}_0}{\text{MVC of each muscle} - \text{Resting EMG}_0} \times 100$$

The onset and duration (sec) of muscle activities during the STS were also computed. Onset was determined when the voltage surpassed the baseline values by at least 3 standard deviations within 25 ms (Oh *et al.*, 2010). The duration of muscle activity was computed by subtracting the offset time from the onset time. The EMG measurement during the STS under each condition of attentional

focus was repeated in 3 trials, and the average value was used for analysis.

### Statistical Analysis

The physical characteristics, %maximum voluntary contraction (%MVC), onset, and duration of muscle activity are expressed as median and interquartile. The %MVC, onset, and duration of muscle activity were analyzed using the Friedman test for within-subject effects. Post hoc means comparisons were performed using the Wilcoxon signed-ranks test. The Mann-Whitney U test was used to analyze the differences for between-subject effects. The level of significance was set at  $p < 0.05$ .

The self-reported response times are presented as the mean and standard deviation. Data were analyzed using a mixed ANOVA with age (young, old) as a between-subject factor, and attentional focus (no focus, visual, muscular, somatosensory) as a within-subject factor. Post hoc means comparisons were performed using the Bonferroni correction. The significance level was shown as  $p < 0.05$ .

## Results and Discussion

### %Maximal Voluntary Contraction

The %MVC of both the rectus femoris and the tibialis anterior was greater than the biceps femoris and the medial gastrocnemius ( $p < 0.05$ ). The pattern of force generation was quite similar between young and older adults, except the %MVC of the biceps femoris and the medial gastrocnemius. For young adults, the %MVC of the biceps femoris was smaller than the medial gastrocnemius ( $p < 0.05$ ), whereas the older adults' %MVC of the biceps femoris did not differ from the medial gastrocnemius in 3 focus conditions, except in the no AF ( $p < 0.05$ ). Young and older participants did not differ and there were also no significant effects of attentional focus conditions on the %MVC (Table 2).

### Onset of Muscle Activity

There was no significant difference in the pattern of onset of muscle activity during the

STS movement with all attentional focus conditions between young and older adults ( $p>0.05$ ). The tibialis anterior and the rectus femoris were activated first during performance of the STS. Also, the onset of tibialis anterior and rectus femoris muscle activity did not differ in the 3 attentional focus conditions ( $p>0.05$ ), except in the EF ( $p<0.05$ ). The onset of rectus femoris muscle activity was also faster than the biceps femoris muscle activity

( $p<0.05$ ). The onset of medial gastrocnemius muscle activity during the STS was the slowest in all attentional focus conditions ( $p<0.05$ ).

The onset of rectus femoris and biceps femoris muscle activity during the STS with no AF was faster than the other attentional focus conditions ( $p<0.05$ ), whereas there was no significant difference between the EF and IF ( $p>0.05$ ). The onset of medial gastrocnemius muscle activity during the STS in the SIF was

**Table 2. %MVC of 4 muscles during sit to stand under 4 focus conditions in young and older adults**

| Muscles                  |                      | Conditions<br>Median [Q1, 3]             |                                          |                                          |                                          |
|--------------------------|----------------------|------------------------------------------|------------------------------------------|------------------------------------------|------------------------------------------|
|                          |                      | No AF                                    | EF                                       | MIF                                      | SIF                                      |
| Young adults<br>(N = 22) | Rectus femoris       | 72.45<br>[51.73, 115.87]                 | 74.80<br>[56.53, 101.01]                 | 74.49<br>[62.34, 111.52]                 | 73.28<br>[56.92, 102.58]                 |
|                          | Biceps femoris       | 18.45 <sup>a</sup><br>[14.28, 28.17]     | 19.04 <sup>a</sup><br>[12.51, 28.87]     | 21.02 <sup>a</sup><br>[13.83, 29.57]     | 19.99 <sup>a</sup><br>[12.58, 27.25]     |
|                          | Tibialis anterior    | 59.42 <sup>b</sup><br>[35.55, 80.58]     | 60.68 <sup>b</sup><br>[42.94, 83.28]     | 61.66 <sup>b</sup><br>[44.56, 90.61]     | 65.06 <sup>b</sup><br>[30.35, 84.99]     |
|                          | Medial gastrocnemius | 27.60 <sup>a,b,c</sup><br>[16.91, 43.91] | 29.36 <sup>a,b,c</sup><br>[16.47, 45.38] | 31.29 <sup>a,b,c</sup><br>[17.09, 58.55] | 31.75 <sup>a,b,c</sup><br>[22.75, 52.14] |
| Older adults<br>(N = 18) | Rectus femoris       | 102.69<br>[58.92, 117.84]                | 100.15<br>[61.55, 130.88]                | 96.37<br>[57.19, 122.54]                 | 88.90<br>[59.89, 119.31]                 |
|                          | Biceps femoris       | 36.93 <sup>a</sup><br>[25.38, 47.00]     | 29.13 <sup>a</sup><br>[22.95, 45.72]     | 34.28 <sup>a</sup><br>[23.78, 54.17]     | 30.35 <sup>a</sup><br>[25.39, 50.26]     |
|                          | Tibialis anterior    | 68.25 <sup>b</sup><br>[47.14, 88.80]     | 55.26 <sup>b</sup><br>[38.86, 110.00]    | 58.40<br>[39.22, 81.44]                  | 54.34 <sup>b</sup><br>[33.63, 88.35]     |
|                          | Medial gastrocnemius | 26.29 <sup>a,b,c</sup><br>[19.47, 39.38] | 25.21 <sup>a,c</sup><br>[13.27, 40.41]   | 24.31 <sup>a,c</sup><br>[15.07, 50.06]   | 27.44 <sup>a,c</sup><br>[17.17, 35.71]   |

Q: interquartile; significant difference was tested by Friedman test, the Wilcoxon Signed Ranks and by the Mann-Whitney U test at  $p<0.05$ ; No AF = no attentional focus; EF = external focus; MIF = muscular-internal focus; SIF = somatosensory-internal focus; <sup>a</sup> = significant difference when compared with rectus femoris ( $p<0.05$ ); <sup>b</sup> = significant difference when compared with biceps femoris ( $p<0.05$ ); <sup>c</sup> = significant difference when compared with tibialis anterior ( $p<0.05$ ).

**Table 3. Onset of 4 muscles activity during sit to stand under 4 focus conditions in young and older adults**

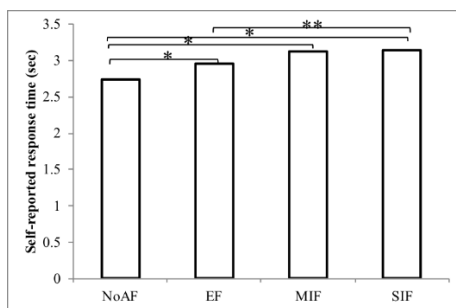
| Muscles                  |                      | Conditions<br>Median [Q1, 3]             |                                          |                                          |                                           |
|--------------------------|----------------------|------------------------------------------|------------------------------------------|------------------------------------------|-------------------------------------------|
|                          |                      | No AF                                    | EF                                       | MIF                                      | SIF                                       |
| Young adults<br>(N = 22) | Rectus femoris       | 0.355<br>[0.250, 0.486]                  | 0.500*<br>[0.266, 0.659]                 | 0.403*<br>[0.273, 0.588]                 | 0.443*<br>[0.328, 0.795]                  |
|                          | Biceps femoris       | 0.393 <sup>a</sup><br>[0.285, 0.671]     | 0.501* <sup>a</sup><br>[0.332, 0.720]    | 0.452 <sup>a</sup><br>[0.340, 0.710]     | 0.587* <sup>a</sup><br>[0.378, 1.065]     |
|                          | Tibialis anterior    | 0.346 <sup>b</sup><br>[0.251, 0.502]     | 0.317 <sup>a,b</sup><br>[0.206, 0.434]   | 0.345 <sup>b</sup><br>[0.240, 0.483]     | 0.447 <sup>b</sup><br>[0.291, 0.714]      |
|                          | Medial gastrocnemius | 0.550 <sup>a,b,c</sup><br>[0.379, 0.869] | 0.765 <sup>a,b,c</sup><br>[0.387, 1.007] | 0.644 <sup>a,b,c</sup><br>[0.400, 0.839] | 0.907* <sup>a,b,c</sup><br>[0.575, 1.178] |
| Older adults<br>(N = 18) | Rectus femoris       | 0.322<br>[0.182, 0.457]                  | 0.405*<br>[0.212, 0.4]                   | 0.344*<br>[0.176, 0.457]                 | 0.450*<br>[0.276, 0.551]                  |
|                          | Biceps femoris       | 0.451 <sup>a</sup><br>[0.266, 0.784]     | 0.476* <sup>a</sup><br>[0.295, 0.734]    | 0.366 <sup>a</sup><br>[0.253, 0.787]     | 0.527* <sup>a</sup><br>[0.337, 0.721]     |
|                          | Tibialis anterior    | 0.413 <sup>b</sup><br>[0.265, 0.542]     | 0.424 <sup>a,b</sup><br>[0.299, 0.557]   | 0.329 <sup>b</sup><br>[0.320, 0.362]     | 0.336 <sup>b</sup><br>[0.255, 0.421]      |
|                          | Medial gastrocnemius | 0.652 <sup>a,b,c</sup><br>[0.398, 1.054] | 0.659 <sup>a,b,c</sup><br>[0.457, 1.282] | 0.660 <sup>a,b,c</sup><br>[0.456, 1.112] | 0.677* <sup>a,b,c</sup><br>[0.489, 1.106] |

Q: interquartile; significant difference was tested by Friedman test, the Wilcoxon Signed Ranks and by the Mann-Whitney U test at  $p<0.05$ ; No AF = no attentional focus; EF = external focus; MIF = muscular-internal focus; SIF = somatosensory-internal focus; \* = significant difference with No AF ( $p<0.05$ ); \*\* = significant difference with EF ( $p<0.05$ ); \*\*\* = significant difference with MIF ( $p<0.05$ ); <sup>a</sup> = significant difference when compared with rectus femoris ( $p<0.05$ ); <sup>b</sup> = significant difference when compared with biceps femoris ( $p<0.05$ ); <sup>c</sup> = significant difference when compared with tibialis anterior ( $p<0.05$ ); # = significant difference between young and older adults ( $p<0.05$ ).

significantly slower than the no AF and MIF ( $p < 0.05$ ). There were no significant effects of the attentional focus conditions on the onset of tibialis anterior muscle activity ( $p > 0.05$ ) (Table 3).

### Duration of Muscle Activity

The duration of tibialis anterior and medial gastrocnemius muscle activity was significantly shorter than that of other muscles in all attentional focus conditions in both the



**Figure 1. Self-reported response time during STS under 4 focus conditions**

No AF = no attentional focus; EF = external focus; MIF = muscular-internal focus; SIF = somatosensory-internal focus; \* = significant difference with No AF ( $p < 0.05$ ); \*\* = significant difference with EF ( $p < 0.05$ ).

young and older adults ( $p < 0.05$ ). Moreover, the duration of biceps femoris muscle activity was shorter than the rectus femoris muscle activity in all attentional focus conditions in young adults ( $p < 0.05$ ), whereas there was no significant difference in the duration of the 2 muscles in older adults ( $p > 0.05$ ).

In young adults, the duration of rectus femoris, biceps femoris, and tibialis anterior muscle activity in the no AF was shorter than in the IF ( $p < 0.05$ ). Only the duration of rectus femoris and biceps femoris muscle activity in the EF was shorter than the IF ( $p < 0.05$ ). Surprisingly, there were no significant effects of attentional focus conditions during the STS on the duration of muscle activity in older adults ( $p > 0.05$ ) (Table 4).

### Self-Reported Response Time

There was a significant main effect of attentional focus ( $F(3, 114) = 14.089$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.27$ ) on the self-reported response time. The self-reported response time in the no AF was shorter than in the EF, MIF, and SIF ( $p < 0.001$ ). The self-reported response time in the EF was shorter than in the SIF ( $p < 0.001$ ). Young and older participants did not differ, and there were no other significant effects on self-reported response times (Figure 1).

**Table 4. Duration of 4 muscles activity during sit to stand under 4 focus conditions in young and older adults**

| Muscles                  |                      | Conditions                             |                                        |                                        |                                        |
|--------------------------|----------------------|----------------------------------------|----------------------------------------|----------------------------------------|----------------------------------------|
|                          |                      | Median [Q1, 3]                         |                                        |                                        |                                        |
| Young adults<br>(N = 22) | Rectus femoris       | 2.030<br>[1.487, 2.323]                | 1.971<br>[1.606, 2.522]                | 2.333***<br>[1.951, 2.784]             | 2.397***<br>[2.080, 2.850]             |
|                          | Biceps femoris       | 1.612 <sup>a</sup><br>[1.164, 1.984]   | 1.639 <sup>a</sup><br>[1.298, 2.134]   | 1.940***,a<br>[1.528, 2.426]           | 1.716*,a<br>[1.328, 2.355]             |
|                          | Tibialis anterior    | 0.482 <sup>a,b</sup><br>[0.316, 0.936] | 0.856*,a,b<br>[0.368, 1.179]           | 0.918*,a,b<br>[0.478, 1.542]           | 0.890*,a,b<br>[0.593, 1.622]           |
|                          | Medial gastrocnemius | 0.834 <sup>a,b</sup><br>[0.465, 1.467] | 0.758 <sup>a,b</sup><br>[0.316, 1.061] | 1.148 <sup>a,b</sup><br>[0.509, 1.581] | 1.250 <sup>a,b</sup><br>[0.567, 1.618] |
|                          |                      | 2.164<br>[1.654, 2.974]                | 2.069<br>[1.338, 3.204]                | 2.695<br>[1.864, 3.192]                | 2.664<br>[1.589, 3.378]                |
| Older adults<br>(N = 18) | Rectus femoris       | 2.164<br>[1.654, 2.974]                | 2.069<br>[1.338, 3.204]                | 2.695<br>[1.864, 3.192]                | 2.664<br>[1.589, 3.378]                |
|                          | Biceps femoris       | 1.906<br>[1.733, 2.700]                | 2.112<br>[1.147, 2.992]                | 2.113<br>[1.466, 2.729]                | 2.135<br>[1.050, 3.206]                |
|                          | Tibialis anterior    | 0.360 <sup>a,b</sup><br>[0.170, 0.651] | 0.661 <sup>a,b</sup><br>[0.272, 1.389] | 0.700 <sup>a,b</sup><br>[0.000, 1.593] | 0.884 <sup>a,b</sup><br>[0.211, 1.436] |
|                          | Medial gastrocnemius | 0.723 <sup>a,b</sup><br>[0.344, 1.154] | 1.000 <sup>a,b</sup><br>[0.318, 1.482] | 1.086 <sup>a,b</sup><br>[0.447, 1.690] | 0.976 <sup>a,b</sup><br>[0.348, 1.425] |

Q: interquartile; significant difference was tested by Friedman test, the Wilcoxon Signed Ranks and by the Mann-Whitney U test at  $p < 0.05$ ; No AF = no attentional focus; EF = external focus; MIF = muscular-internal focus; SIF = somatosensory-internal focus; \* = significant difference with No AF ( $p < 0.05$ ); \*\* = significant difference with EF ( $p < 0.05$ ); \*\*\* = significant difference with MIF ( $p < 0.05$ ); <sup>a</sup> = significant difference when compared with rectus femoris ( $p < 0.05$ ); <sup>b</sup> = significant difference when compared with biceps femoris ( $p < 0.05$ ); <sup>c</sup> = significant difference when compared with tibialis anterior ( $p < 0.05$ ); # = significant difference between young and older adults ( $p < 0.05$ ).

The STS movement contains the movement of leg joints, for example, hip, knee, and ankle joints, and requires lower extremities' muscle strength. The significant leg muscles activated during the STS movement include the quadriceps, hamstrings, gastrosoleus, and tibialis anterior, with most activity in the quadriceps, which requires forces up to 72% (Roebroeck *et al.*, 1994; Galli *et al.*, 2008; Bohannon *et al.*, 2010). This conforms with the present study that the rectus femoris was activated to get contracted from the initial phase of the STS movement. Also, it generated more force than the other muscles, especially the bicep femoris and the gastrocnemius. Moreover, the rectus femoris was activated throughout the STS movement. It could be noticed that it had a longer duration of contraction than the other muscles, because the rectus femoris is the key muscle for knee extension to keep the standing posture. The biceps femoris and the gastrocnemius are synergist muscles to help with hip and knee extension, respectively, and to help standing stability, so these 2 muscles are activated more slowly and with less force production than the rectus femoris. When comparing the function of the biceps femoris and the gastrocnemius, the biceps femoris was activated to start contraction before the gastrocnemius, and the activation duration was longer than that of the gastrocnemius, because the biceps femoris helps hip extension from the initial phase of the STS movement until it is complete. In contrast, the gastrocnemius is the muscle helping stability and knee extension (Roebroeck *et al.*, 1994), and is therefore activated in the later phase. As a result, the current study showed that the gastrocnemius had a later onset and shorter duration of activation than the other muscles.

Although the force production of the tibialis anterior in this study was less than that of the rectus femoris, it was not statistically different. The tibialis anterior also plays an important role during the STS movement, especially from the initial phase. Khemlani *et al.* (1999) studied the STS muscles and found that, at the initial phase, the body had a forward momentum and the body weight was

transferred down to the feet. As a result, the tibialis anterior contracts for stability during the body's forward movement. This muscle was activated most during the initial phase of the STS movement. Consequently, the duration of contraction was not as long as that of the rectus femoris. These findings from the current study were similar to a number of previous studies of STS biomechanics; for example, the study of Roebroeck *et al.* (1994) who studied the biomechanics and muscle activity during the STS movement. The findings revealed that the hamstrings worked with the rectus femoris to help leg extension, especially in the transition phase. The tibialis anterior was greatly activated in the acceleration phase (initial phase), and the gastrocnemius was activated in the deceleration phase for stability.

In the present study, the findings revealed that all patterns of muscle activities, for example, the %MVC, onset, and duration of muscle activation, were in compliance with all conditions of attentional focus in both the young and older participants. Only the STS voluntary force of the biceps femoris and the medial gastrocnemius were different between these 2 groups. To clarify, the biceps femoris' voluntary force in young adults was less than the medial gastrocnemius, whereas such function in the elderly was not different. That might be because of the STS patterns in the elderly being different from young adults (Schultz *et al.*, 1992; Hughes *et al.*, 1994). For example, the study of Hughes *et al.* (1994) found that the elderly perform their STS movement by stabilization strategy. They leaned the trunk forward so much that the center of mass fell down between feet, leading to large hip flexion angles. As a consequence, more momentum force was required for the hip extension. The biceps femoris might have to produce more force to extend the hip joints. For young adults, they performed the STS movement by momentum strategy; in other words, using the momentum from body movement to help the STS movement. Nevertheless, this study did not measure kinematic data during monitoring the EMG. Therefore, future studies should conduct kinematic and EMG analysis during the STS

movement under different conditions of attentional focus in order to understand the age-related mechanism of the STS movement.

Although this study did not show any differences of leg muscle contraction force in each condition of attentional focus, the durations of the STS movement measured by the self-reported response times of the EF and IF were longer than that of the no AF. The STS movement is a common movement in our daily life and has become one of most common automatic skills, with no need of attention for information processing to command such a movement, and thus it happens rapidly (Schmidt and Lee, 1999; Shumway-Cook and Woollacott, 2007). This is in line with this study which found that the STS movement under the condition of no AF took the shortest time. Abundant studies of the effects of attentional focus to movement efficiency and effectiveness have focused on the comparison between the EF and IF. The comparison of the effects of the no AF is still being neglected. Most findings of those studies revealed that the EF during movement capability is better than the IF (Wulf and Prinz, 2001; Wulf *et al.*, 2004; Wulf and Su, 2007; Wulf *et al.*, 2009; Lohse *et al.*, 2010; Wulf *et al.*, 2010; Jackson and Holmes, 2011; Marchant and Greig, 2017). The present findings revealed that the EF during movement produced a slower movement than the no AF during movement, although movement with the EF activated automatic movement control. This might be because the effect of the EF is to reduce conscious control and to activate automatic movement control (Lohse *et al.*, 2010). Even so, attention still remained at a certain level, causing slower information processing than no focus of attention. This is an interesting issue for further studies of advanced brain function during no focus as well as the focus of attention during movement.

Regarding the STS movement with the SIF, it took longer than the EF. This was not surprising though, and it was in accordance with several previous studies. The IF allows the performer to consciously control the component and sequence of their movements, resulting in degrading the performance (Lohse

*et al.*, 2010). However, an interesting point in this study is that the STS movement with the MIF was not different from the EF in terms of the response time. If considering the effects of muscle activity too, especially the rectus femoris as the key muscle for the knee extension, it could be apparently seen that the onset of rectus femoris activation during the STS movement between the EF and IF was not different. However, the duration of rectus femoris contraction during the same movement with the IF under the 2 conditions was longer than that of the EF, especially in young adults. This might be due to the adjustment of the information processing and motor command procedures of stimulus identification, response selection, and response programming, to produce proper force, time, and muscles for their functional activity. If measuring the response time by EMG, the time could be divided into the premotor reaction time, as the functional time of the central nervous system, concerned with the perception of information and decision-making on response, and the motor reaction time, as the time that the central nervous system needs to command muscles to start contraction. The time from muscle contraction start until finish was called the movement time. And the total time from stimuli that activated movement until it was finished was called the response time (Schmidt and Lee, 1999).

For young adults under the condition of the MIF, the motor reaction time and movement time could be adjusted. Specifically, response preparation might be adjusted and the start of response programming might be lengthened to produce proper force, time, and muscles for their function. Simultaneously, the premotor reaction time might be shortened. As a result, the total response time would be faster. Still, the condition of the SIF, with overall delay of the STS movement, might be owing to the adjustment of the motor reaction time and movement time. Only the response preparation was adjusted and the start of response programming was lengthened, resulting in a longer response time. In contrast, the time of muscle contraction during the STS movement in the elderly was equal in all

conditions, but the response time of the STS movement with the SIF was longer than the other conditions. This might be owing to the delayed premotor reaction time, indicating delayed perception and response selection in the elderly. This divergence of older participants' performance also points to age-related changes in the coupling between task-level action planning and effector-level motor control (Wolpert and Kawato, 1998), whereby direct attentional focus on the latter may reduce the ability to translate behavioral goals into motor plans and effector control (Haaland *et al.*, 1993; Trewartha *et al.*, 2009). Nonetheless, this study did not measure brain function, and future studies could therefore conduct brain evaluation during the STS movement under different conditions of attentional focus.

The limitations of this study were the small sample size and some uncontrolled factors that have an influence on muscle contraction force, such as muscle size and strength. The present research controlled the physical activity level and BMI which also affected the contraction force. The participants, who were recruited, had a normal BMI and a sedentary lifestyle. As a result of uncontrolled muscle factors, this may lead to the wide range of %MVC. Therefore, further studies should be concerned about muscle factors which influence muscle contraction force, and should also recruit a larger number of participants to take part in the study.

## Conclusions

In the current study, the findings mainly showed 3 potential impacts of attentional focus on the planning and execution of the STS movement. Firstly, the patterns of muscle activities were in compliance with all conditions of attentional focus, except for the voluntary force of the biceps femoris and the medial gastrocnemius. This might be because of the strategy of the STS movement in the elderly being different from in the young adults. Secondly, both the young and older participants' self-reported response times of the EF and IF were longer than that of the no

AF. This might be because the EF was to reduce conscious control and to activate automatic movement control. Subsequently, attention still remained at a certain level, causing slow information processing. The IF allows the performer to consciously control the component and sequence of their movements, which requires attention, resulting in slow information processing. Finally, both age groups showed that the STS movement with the SIF generated longer self-reported response times than the EF, whereas the STS movement with the MIF was not different from the EF. In contrast, there was an age-related difference in the duration of muscle contraction, especially the rectus femoris. For young participants, the time of muscle contraction during the STS movement under the IF was longer than that of the EF, while the duration of muscle contraction in the elderly was equal in all conditions. This might be because of the difference in adjustment of the information processing and motor command procedures under different foci of attention between young adults and the elderly. To sum up, although there was a difference in strategy used for the STS movement between age groups, the executions of the STS movements were quite similar. Also, the qualities of the STS movements under attentional focus, in terms of force generation, onset, and duration of muscle contraction were quite similar. Importantly, it is worth knowing that focus instruction still has an influence on movement efficiency. Although the qualities of the STS movement under attentional focus were quite similar, one kind of IF showed a slow processing time to perform the STS movement. Thus a health team or trainer should consider how to apply attentional instruction to perform the STS movement efficiently.

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