Pattern of Muscle Activation During Sit to Stand Task in Feet Forward with 80° Knee Flexion using Surface EMG

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Abstract: The sit-to-stand (STS) in feet forward is one type of STS with a characteristic of delayed contraction of Tibialis anterior. Surface EMG (sEMG) signals are recorded by non-invasive electrodes and are preferably used to obtain information about the time or intensity of superficial muscle activation. This study aims to find the pattern of muscle activation when STS in feet forward. This is a retrospective study using sEMG for the pattern of muscle activation of 14 males and 14 females in Hasan Sadikin General Hospital Bandung Indonesia, in March 2019. The average height, weight, body fat, and fat-free mass in men were significantly different from women participants. The muscle activation of muscle group stabilizer (Rectus Femoris (RF) and Biceps femoris lateral (BFL)) is bigger than muscle group sequence (Tibialis anterior (TA) and Gastrocnemius medialis (GM) during STS in this research. Rectus femoris was the muscle that had the highest mean maximum force in every STS phase. The mean maximum force of RF, BFL, and GM in Phase II was the highest compared to another phase. On the other hand, the mean maximum force of TA was the highest in Phase V. Feet Forward with 80° knee flexion is the strategy foot positioning during sit to stand to increase the force of sequence muscle group than stabilizer muscle group

1 INTRODUCTION

Sit to stand movement is a movement that is frequently done by people. This ability is an important skill that is considered as a fundamental task for daily activities and is a prerequisite for functional independence. (Carr JH, 1992; Shepherd RB & Koh HP, 1996; Ng, Shamay S M, et al, 2015).

Sit To Stand (STS) is a movement of the body's center of mass (CoM) upward from a sitting position to a standing position without losing balance. (Roebroeck et al, 1994) An individual needs to bring his CoM from a relatively large and stable base of support in sitting to a considerably smaller base of support in standing. To achieve this transition, CoM must first move forward then reach its maximal velocity at the preparatory phase. At seat-off, CoM switches into vertical movement and its velocity continues to accelerate until it reaches a maximum in the middle of the extension phase. Subsequently, the CoM velocity decelerates progressively until reaching zero, when the standing position is achieved. (Hirschfeld, 1999).

In the literature, two ways to performed STS define the strategy for implementing the STS task were found. Defined as the "momentum-transfers strategy," the first method implies that the subject in question makes a small trunk flexion of the weight transferring forwards and then begins the separation of the seat, ending with the starting foot. This form is most common among healthy people. Another way to make the sequence is increasing trunk flexion before starting to move from the chair, which is usually performed by people with muscle weakness in the legs. If the results obtained in this study are analyzed, in both groups four muscles act primarily as stabilizers of motion (tibialis anterior, rectus abdominis, soleus) and others that are responsible

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for implementing the sequence (quadriceps rectus femoris, quadriceps vastus medialis and biceps femoris. (Antoni I, 2013).

STS strategy related determinants such as speed, foot positioning, trunk positioning, arm movement, terminal constraint, fixed joint, knee position, and training. (Lamberts, 2008) Individual normal healthy, using 100o knee flexion during STS task and shows muscle activation of stabilizer group muscle is bigger than sequence group muscle. (Antonio I et al, 2013; Brunt, 2002) Stroke patients are reported have weakness in the lower extremity, making it difficult to do STS. Sit to stand in stroke patients is reported to have a longer duration than normal. (Baukadida et al., 2015). It was reported that in hemiplegia patients, usually using feet forward strategy 750 knee flexion in foot positioning during STS. The foot positioning of an uninvolved limb in feet forward, an extended position (75o of knee flexion) and normal position (100o of knee flexion) in involved limb causes the activity muscle of the sequence group bigger than stabilizer. (Brunt, 2002)

A step foot position during the STS task by manipulating the foot placement of the unaffected limb was proved will improving the static and dynamic postural balance in patients with hemiplegia (Han Jintae, Kim youngmi, Kim Kyung, 2015). Few studies have described the effect of the nonparetic foot positioning during STS in patients but there is no standardization about the degree of foot positioning. Therefore, in this pilot study, we want to investigate muscle activity of stabilizers group muscle and sequence group muscle in STS task in feet forward position (80o of knee flexion) in healthy younger adults to add information about foot positioning impact. Hopefully, the result will be developed to a bigger study to find out the standardization method of STS procedure that effective for patients with stroke to achieve better performance with their paretic limb.

2 METHODS

Twenty-eight participants, 14 males, and 14 females, in Hasan sadikin Bandung Indonesia, General Hospital were recruited in March 2019. Participants were included if their age between 20-35 years old, able to walk without an assistive device and had no heart, vascular, lung or bone/joint problems that may impaired standing activity from a chair. Participants were excluded if have a musculoskeletal deformity, muscle weakness, and pain. The study was approved by the Faculty of Medicine Universitas Indonesia ethical committee (No.0438/UN2.F1/ETIK/2018) and written consent was obtained from all participants prior take part in this study. Before measurement was taken, each participant was given an explanation about the sit to stand (STS) protocol and make a trial of the movement for familiarization. All of the participants were instructed to seat with feet forward (800 knee flexion) in a chair without arm support (F. R. Goulart and J. Valls-Sol´e, 1999). Their arms were being folded across their chest in all of the phases of STS, with their feet being open wide align with the shoulder. Each subject performed three times of STS with the speed transition of each phase of STS indicated by a metronome. The values considered for statistical analysis were the best score of maximal voluntary contraction.

The muscle activity (MA) was recorded using surface electromyography (sEMG) machine (Gymna, type myo 200, Belgium). Muscles that evaluated were muscle group sequences such as Rectus Femoris (RF), Biceps Femoris (BFL), and muscle group stabilizer such as Tibialis Anterior (TA), Gastrocnemius (GM). On each muscle three circular adhesive Ag-AgCl electrodes were placed based on SENIAM (Surface EMG for non-invasive assessment of muscles) protocol guidance at a distance of two inches between the electrode (figure 1) (I Antonio et al, 2013)

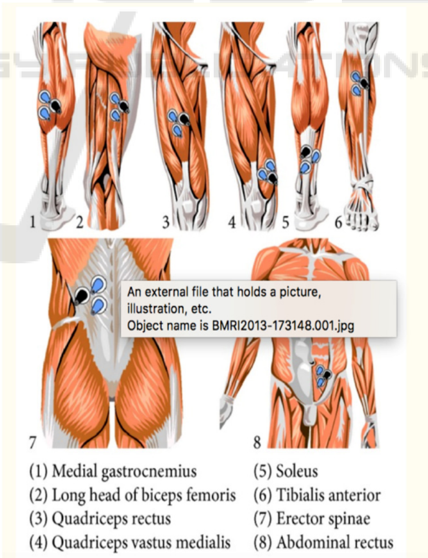

Figure 1: Schematic placement of surface electrodes on each muscle. From MegaWin 3.0.

The STS movement for analysis is classified into 6 phases based on Schenkman et al study. The seat-off, which refers to the moment when only the feet are in contact with the grounds and no force is applied on the seat, is often used to identify STS phases. Phase I (flexion-momentum phase) starts with the initiation of the movement and ends just before the buttocks/thighs are lifted from the seat of the chair. Phase II (momentum-transfer phase) begins as the buttocks are lifted and end when maximal ankle dorsiflexion is achieved (anterior and upward CoM displacement). The anterior displacement of the CoM brings it close to the center of pressure (CoP) to reach a quasi-static stability position. Phase III (extension phase) is initiated just after maximum ankle dorsiflexion and ends when the hips first cease to extend; including leg and trunk extension. Phase IV (stabilization phase) begins after hip extensions are reached and end when all motion associated with stabilization is completed. Phase V is reverse-phase II and Phase VI is reverse-phase I. (Janssen et al, 2002; Boukadida A et al, 2015; Schenkman M, 1990).

This research is a descriptive, cross-sectional study with the convenient sampling method. The data collection was analyzed using IBM SPSS statistical software version 20. Independent Samples Test and Mann Whitney test was used to compare demographic characteristics between different gender of the subject.

3 RESULTS

Table 1 showed there were differences in the anthropometry of the sample between women and men, except the age.

Table 1: General characteristics of participants.

Characteristics	Men	Women	p-Value
	Mean(SD)	Mean(SD)	
Age (years)	30,86(4,52)	30,71(2,46)	0,918
Height (cm)	167,57(4,48)	158,43(6,21)	<0,001*
Weight (kg)	71,96(7,52)	59,64(11,79)	0,003*
Body Mass Index (kg/m^2)	25,67(2,99)	23,66(3,82)	0,133
Body Fat (%)	22.08 (4.41)	32.15 (7.04)	<0.001*
Fat-free mass (kg)	52.90 (3.16)	37.29 (4.23)	<0.001*

Note: *p-value<0.05 indicates the significant predictors in the model; SD: Standard Deviation

Table 2: The mean maximal force of Rectus Femoris, Biceps Femoris Lateral, Gastrocnemius and Tibialis Anterior muscle in each phase of Sit-to-Stand.

Muscle	Phase I (μV)	Phase II (μV)	Phase III (μV)	Phase IV (μV)	Phase V (μV)	Phase VI (μV)
RF	37,37	73,11	51,60	50,99	61,74	37,28
BFL	19,07	47,97	23,87	27,53	36,90	17,28
GM	11,77	22,77	19,99	20,13	17,95	11,53
TA	17,80	31,05	23,25	23,98	35,87	15,90

Note: RF: Rectus Femoris muscle, BFL:Biceps femoris lateral muscle, GM: Gastrocnemius muscle, TA:Tibialis Anterior muscle

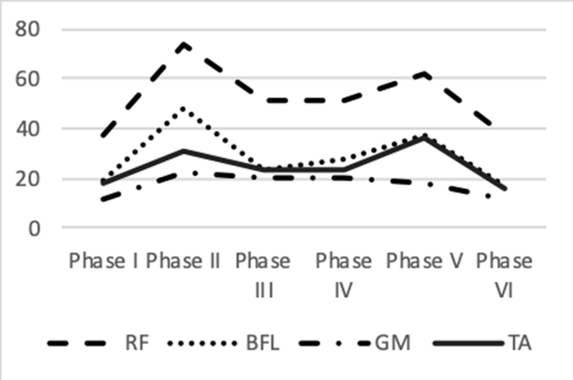

Figure 2: An overview of muscle activation of RF, BFL, GM AND TA using sEMG evaluation during all STS Phases.

In phase II, all muscle group have the biggest muscle activation compare to another phase, and the muscle group sequence was bigger than muscle group stabilizer. The rectus femoris has the biggest muscle activation in all phases. On the other hand, the mean maximal activation of TA was the highest in Phase V. The overview of mean maximal force for RF, BFL, GM and TA in each phase was also described in Figure 2.

4 DISCUSSIONS

The subjects of the study were mostly men (90,9%). Although women could have higher CRP levels than men due to hormonal factors (O'Connor, 2009), this condition may not significantly influence the CRP results.

CRP levels did not change significantly due to several factors, one of them is the high CRP level since the beginning, although there was no sign of infection during the study since the leucocyte count did not increase. The CRP level could be influenced by BMI, the level and severity of the lesion and smoking habits. Most of the subjects in this study were included in the underweight category with an average BMI was 18.72 ± 2.173 kg/m2. The BMI values are related to body fat composition. Low BMI could be caused by decreased fat-free muscle mass due to reduction in physical activity and atrophy caused by paralysis. Greater adipose tissue composition due to impaired fat and carbohydrate metabolisms can lead to increased CRP levels (Wang, 2007).

Lesion levels and severity of SCI itself can influence the CRP levels. The higher lesion levels and severe SCI indicate higher CRP levels. Those with tetraplegia have a greater risk of CVD compared to those with paraplegia in chronic SCI Gibson, 2008). SCI lesions of the subjects in this study were as high as the thoracic cord. Since most of the subjects had complete SCI, high CRP levels of the subjects were discovered since the beginning.

The smoking habits were not limited during the study, these may cause a high of CRP level. Smoking can increase the release of proinflammatory cytokines in the blood and lung circulation. It also can cause oxidative stress and vascular inflammation occurs marked by increased IL-6 and CRP levels. A previous study presented that higher CRP levels were mostly found in the subjects who smoked (O'Connor, 2009). Unfortunately, this study did not have any data to analyaze the correlation between the number of cigarettes (packs per year) and nicotine levels with distinctive measurements in each subject.

Exercise can decrease inflammatory cytokines in the blood (Alves, 2013). Muscle contractions can stimulate the release of IL-6 from muscle cells, namely muscle derived IL-6. IL-6 has important anti-inflammatory effects since it plays a role in the formation of anti-inflammatory cytokines such as interleukin-1 receptor antagonist (IL-1ra) and interleukin-10 (IL-10). The appearance of IL-10 and IL-1ra in the circulation contributes to mediating the anti-inflammatory effects of exercise and induces a reduction in CRP levels and suggests that physical activity may suppress systemic low-grade inflammation.

The increased plasma IL-6 is related to exercise intensity, duration, the mass of muscle recruited and one's endurance capacity (Peterson, 2005). Physical activities with moderate intensity are recommended to reduce CRP levels (Zonneveld, 2014). IS exercise in this study counted as moderate intensity based on Borg scale 11-13. Most of the subjects had the same occupation as a craftsman and did their daily activities independently, but still there were no complete data and objective assessment of physical activities collected.

The IS exercise given in this study had not decreased the inflammation marker of CRP. This study given different result from the previous studies that after 4 weeks of physical training was associated with significantly improved plasma concentrations of adiponectin and CRP (Oberbach, 2006), IS exercise for 4 weeks (twice daily, 30 breaths a set for 30 days) in COPD patients was already showed a significant result in reducing IL-6 and TNF-α inflammatory cytokines (Leelarungrayub, 2017), IMT combined with aerobic training provides additional benefits in functional and serum biomarkers of inflammation (CRP) in patients with moderate CHF (Adamapoulos, 2014). The differences in the type of exercise, the mass of muscle recruited, the intensity and duration of exercise compared with the previous study, the markers of inflammation which had been examined may make the differences of the result.

The study has shown that IS exercise can improve lung function in an individual with chronic SCI. The similar results showed in another previous study (Kim, 2017). The study has not shown significant change in the circulating level of CRP however, a potential local effect of IS on diaphragmatic myocyte cytokine production cannot be excluded. Whether there was a reduction in local diaphragmatic muscle inflammation marker after IS was not tested in this study.

The IS exercise given in this study had influenced fat metabolism marked by the significant reduction of LDL/HDL ratio. IL-6 is the first cytokine released into the circulation during exercise, derived from the contracting muscle. This cytokine will activate lipolysis independently of elevations in Growth Hormone (GH) and/or cortisol and become a potent catalyst for fat oxidation in muscle cells (Peterson, 2005). The present study was given different result from the previous studies that IMT with low inspiratory loading fails to demonstrate any significant improvements in blood glucose levels, serum lipids, and/or HOMA-IR in female patients with type 2 diabetes (Ahmad, 2017) and after 7 days of IMT had not able to change metabolic variables (blood glucose and lipid profile) in women with metabolic syndrome (Feriani, 2017).

There are some limitations to this study that can be improved in future research. Firstly, the present study did not measure other cytokines, such as IL-10 and IL-1ra may be needed to confirm that the observed increase in IL-6 is muscle derived and not due to other factors, such as the existence of a catabolic/inflammatory state due to exercise training (Peterson, 2005). Secondly, this study did not have any data regarding the number of cigarettes (packs per year) and nicotine levels with distinctive measurements in each subject which can correlate with the inflammatory state. Thirdly, there was no complete data and objective assessment of physical activities and nutritional intake collected.

Further study can be conducted by giving longer-term IS exercise intervention or with other exercise combinations including aerobics. Assessment of detail physical activity level, other routine activity (such as smoking), nutritional status and other anti-inflammatory cytokine levels should be done in further study.

5 CONCLUSIONS

A 4 weeks incentive spirometry breathing exercise resulted in improvement in lung function and lipid ratio. Improvement in lung function has not influenced the systemic inflammatory level (CRP), although a beneficial influence on LDL/HDL ratio was recorded. Further follow up and studies are required to establish the role of inspiratory muscles in improving the systemic inflammatory status of patients with chronic spinal cord injury.

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