Comparison of muscle activity during sit-to-stand movement at different chair heights between obese and normal-weight subjects

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INTRODUCTION

Obesity is one of the commonest health-problems in industrialized countries (Sibella et al., 2003). As directly measuring body fat to diagnose obesity is complex and costly, obesity is generally categorized using body mass index (BMI), which is calculated as the weight (kg) divided by the square of the height (m²) (Kim and Park, 2017). BMI is indirect measurement, and does not perfect distinguish between body fat and lean body mass, however, BMI is strongly correlated with body fat levels (Kim, 2016). Adults in the Asia-Pacific Region are considered to be obese when their BMI is ≥25.0 kg/m², overweight when their BMI is ≥23.0 kg/m² and < 25.0 kg/m², and normal when their BMI is ≥18.5 kg/m² and < 23.0 kg/m² (Kim and Park, 2017). Kim (2016) reported that BMI is not as accurate a predictor of body fat in the elderly as it is in younger and middle-aged adults. Previous studies were conducted on the association between various variable and obesity (Jang et al., 2016; Maffiuletti et al., 2007) and movement analysis (Galli et al., 2000) based on BMI in young adults.

Obesity can lead to comorbidities, the severity of which is proportional to excess body fat (Ryan et al., 2011). Obesity is related to a variety of musculoskeletal abnormalities in adults, which interferes with quality of life and functional capacity and increases healthcare costs (Anandacoomarasamy et al., 2008). Obesity can affect skeletal muscle function and thereby reduce movement of obese individuals (Teasdale et al., 2013). Several studies have described the negative effects of obesity such as systemic locomotor and musculoskeletal problems including weight bearing and postural balance changes (de Souza et al., 2005; Greve et al., 2007; Hills et al., 2001). Obesity alters kinematics during daily life activities such as sit-to-stand (STS) movement, contributing to the development of lower extremity joint injury, pain, and physical...
limitations (Runhaar et al., 2011). Previous studies reported that
kinematic difference between normal and obese subjects during
STS (Sibella et al., 2003), but it is still poor how muscles affect
strategic components of STS in obese subjects. The strategies ad-
opted by obese patients in STS movement can be analyzed to im-
prove the design of rehabilitative treatment assessments (Galli et
al., 2000).

STS movement is necessary for upright movement and other
important daily activities (Bohannon et al., 2008). Thus, STS per-
formance is fundamental for independence (Janssen et al., 2010).
Within-subject factors such as knee extensor strength (Yoshioka
et al., 2014), body mass (Huffman et al., 2015), initial foot position
(Walaszek et al., 2017), and changes in seat height (Skowroński et
al., 2009) contribute to STS performance. STS is an important
functional task that may become difficult to execute in obese pa-
ients due to muscular weakness and other conditions (Galli et
al., 2000).

STS motion requires optimal neuromuscular coordination and
postural adjustments to control moment changes and prevent ex-
cessive energy generation or loss of balance (Papa and Cappozzo,
2000). The quadriceps is a primary motor muscle in STS, promot-
ing knee extension and contributing to hip flexion and stability
(Khemlani et al., 1999). The tibialis anterior (TA) is also import-
dant during the initial phases of the STS, to stabilize the foot on
the ground (Lomaglio and Eng, 2005). The function of the erector
spinae (ES) in STS movement is to provide early contraction and
trunk extension, counteracting excessive trunk flexion (Fotoohab-
ad et al., 2010). Previous studies have reported the differential ac-
tion of related muscles during STS motion when the initial seated
posture changed (Goulart and Valls-Sole, 1999). Thus, the muscle
activity of the lower limbs may change according to chair height
during STS (Arborelius et al., 1992).

STS is an important functional task that may be more difficult
for obese subjects to perform due to weight conditions, muscular
weakness, and lower back pain. Recent studies have focused on
kinetic and kinematic (Sibella et al., 2003) changes and lower limb
muscle activity (Bollinger et al., 2019) during STS among obese
subjects; however, few studies have explored the differences in
muscle activity of the lower limb and trunk muscles according to
chair height during STS motion among obese subjects. Therefore,
in this study, we compared the electromyography (EMG) charac-
teristics of lower limb muscle and trunk muscle at different chair
heights during STS movement between obese and normal-weight
subjects.

MATERIALS AND METHODS

Participants

A total of 26 participants (13 normal weight subjects and 13
obese subjects) were recruited in the study. The inclusion criteria
were: (a) able to stand from an armless chair; (b) no muscular-skel-
etal pathologies; (c) no pain during movements; for normal weight
the inducing, criteria were BMI 18.5–22.9 kg/m²; for obese
group the inducing, criteria were BMI > 25 kg/m². Ethics approv-
al for this study was obtained from the Ethics Committee of the
Kaya University (Kaya IRB-303). All participants were informed
of the study’s purpose and content prior to the study.

Instrumentation

EMG activities of the three muscle on the lower limb and trunk
during STS were recorded using surface Trigno wireless system
(Delsys, Boston, MA, USA) and pairs of silver-silver chloride dis-
posable electrodes with a diameter of 3 mm (EL 503, Biopac sys-
tems Inc., Goleta, CA, USA). The sampling rate was at 2,000 Hz.
The EMG activity recording period of 5 secs. The threes in lower
limb and trunk, were positioned over the muscle fibers of the rec-
tus femoris (RF), TA, and the ES (Hermens et al., 2000). EMG
data were normalized to reference voluntary contraction (RVC),
the RVC testing was performed in subjects positioned in the quiet
sitting. The data obtained from each trial were expressed as a per-
centage of the RVC.

Experimental procedure

Sit-to-stand maneuvers were performed from a chair without an
arm rest. Chair heights were set at 40 cm, 50 cm, 60 cm (Yoshio-
ka et al., 2014). STS began when a verbal signal from the tester.
The movement strategy such as feet position, movement speed,
and movement pattern was not restricted. This experiment was
conducted in a random sampling manner. All subjects had to re-
peat the required motion for each height 3 times, taking a 2-min
break between each repetition.

Statistical analysis

Data will analyze using IBM SPSS Statistics ver. 20.0 (IBM
Co., Armonk, NY, USA). The general characteristics were ana-
lyzed descriptive analysis. For identifying the normal distribution
of data, the Kolmogorov–Smirnov test has been done before the
statistical analysis. A one-way analysis of variance was used to
compare the muscle activation according to the chair height
during the STS on each group and Bonferroni method was used
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RESULTS

General characteristics of the participants
The research participants included 26 male adults. Normal weight group average age was 19.7 ± 1.25 years old, average height was 171.5 ± 6.76 cm, average body weight was 59.3 ± 6.76 kg, and average BMI was 20.3 ± 1.07 kg/m². Obese group average was 19.9 ± 1.44 years old, average height was 173.2 ± 10.4 cm, average body weight was 89.3 ± 21.71 kg, and average BMI was 30.5 ± 4.4 kg/m² (Table 1).

The comparison of muscle activation according to chair height during STS on normal weight and obese subjects
There were significant differences between TA, RF, and ES muscle activation at all chair height on normal weight and obese subjects (P < 0.05) (Table 2). The muscle activation of TA showed significantly higher than RF muscle activation during STS at all chair heights in both group (P < 0.05) (Figs. 1, 2). The muscle activation of TA showed significantly higher than ES muscle activation during STS at all chair heights in obese subjects (P < 0.01) (Fig. 1). By contrast, there was no significant difference between TA and ES muscle activation during STS at all chair heights in normal weight subjects (Fig. 2).

The comparison of muscle activation between normal weight and obese subjects during STS
The TA muscle activation was no significant difference between normal weight subjects and obese subjects at all chair heights (Table 3). The muscle activation of RF and ES showed significantly higher in normal weight subjects than obese subjects at 40 cm, 50 cm of chair heights (P < 0.05) (Table 3).

DISCUSSION

Obesity can affect skeletal muscle function, reducing movement
of obese peoples (Teasdale et al., 2013). Obese subject showed alters kinematics during STS movement compare to normal weight (Sibella et al., 2003), but it is few studies how muscles affect strategic components of STS in obese subjects. Therefore, this study investigated that difference in muscle activity during STS of obesity and normal weight.

This study observed higher muscle activity in the TA than the RF at all chair heights during STS movement in both groups. In a previous study, the TA showed the highest muscle activity during STS movement in a chair that was 43 cm tall among healthy subjects (Cuesta-Vargas and González-Sanchez, 2013); our findings are consistent with those findings. The TA is the first muscle to activate during STS, as an anticipatory postural activity that sets the center of gravity in the optimal position to stretch the more anterior components of STS in obese subjects. Therefore, this study investigated that in normal weight and obese subjects during STS.

Present study showed that difference to between TA and ES muscle activity in all chair heights during STS performance in obese subjects but not in normal-weight subjects. STS is initiated by trunk flexion to provide horizontal momentum and shift the center of gravity forward; therefore, trunk flexion is the major kinematic strategy for improving STS performance (Walaszek et al., 2017). Normal-weight subjects rise from a chair by flexing the trunk forward and maintaining their feet in the initial position, whereas obese subjects limit forward trunk flexion and move their feet backwards from the initial position (Sibella et al., 2003). Obesity typically results in a more erect posture during STS (Galli et al., 2000; Sibella et al., 2003), suggesting that body mass may limit trunk flexion during this task. Body volume tends to alter kinematics during gait, independent of mass (Westlake et al., 2013); therefore, body volume may be a major driver of altered kinematics during STS in obese subjects (Bollinger et al., 2019). It appears that obese subjects use the trunk extensor less than normal-weight subjects during STS, which may explain the differences in TA and ES muscle activity observed between obese and normal-weight subjects during STS in this study.

In the present study, RF muscle activity differed between obese and normal-weight subjects according to chair height during STS. At low seat height, higher load is imposed to the legs during STS movement (Ellis et al., 1984). Because seat height determines the load of STS movement (Janssen et al., 2002) and the thigh muscles contribute greatly to the achievement of this task (Corrigan et al., 2001), the subject’s dependence on thigh muscle activity is higher at low seat height. In addition, as seat height decreases, the knee flexion angle and moment will increase, leading to higher demand on the quadriceps to extend the knee as the body weight is lifted (Arborelius et al., 1992). Quadriceps muscle strength and power, relative to body mass, are lower in obese subjects than in nonobese subjects (Maffiuletti et al., 2007). By contrast, obese subjects have higher absolute knee extensor strength, but lower functional knee extensor strength, relative to body mass, for weight-bearing activities than normal-weight subjects (Tsiros et al., 2013). The amount and location of fat also appear to be associated with muscle function (Marsh et al., 2011). A previous study reported that obese subjects had twice as much intermuscular fat than normal-weight subjects, resulting in slower contraction velocity and reduced power generation (Choi et al., 2015). This finding is consistent with the hypothesis that muscle fat has a negative impact on muscles important for locomotion (Hilton et al., 2008). Total fat mass has been implicated as a predictor of functional decline, and fat infiltration into skeletal muscle has been found to be associated with lower muscle power (Sipila et al., 2004), as well as slower walking speed and chair rise times (Visser et al., 2002). Older adults with obesity have greater muscle mass and volume and higher absolute peak torque, but lower peak knee extensor torque normalized to thigh

Table 3. The comparison of muscle activation between normal weight and obese subjects during STS

| Muscle | Height | BMI   | r     | P-value |
|--------|--------|-------|-------|---------|
| TA     | 40 cm  | Normal: 242.03 ± 63.96 | 1.067 | 0.296   |
|        |        | Obese: 218.64 ± 46.38  |       |         |
|        | 50 cm  | Normal: 235.32 ± 73.09  | 1.041 | 0.308   |
|        |        | Obese: 208.17 ± 58.10   |       |         |
|        | 60 cm  | Normal: 217.19 ± 39.20  | -0.065| 0.948   |
|        |        | Obese: 218.19 ± 39.47   |       |         |
| RF     | 40 cm  | Normal: 167.96 ± 57.71  | 2.725 | 0.017*  |
|        |        | Obese: 123.00 ± 14.44   |       |         |
|        | 50 cm  | Normal: 159.36 ± 50.68  | 2.347 | 0.035*  |
|        |        | Obese: 125.21 ± 13.58   |       |         |
|        | 60 cm  | Normal: 153.06 ± 29.08  | 1.954 | 0.064   |
|        |        | Obese: 133.82 ± 20.34   |       |         |
| ES     | 40 cm  | Normal: 205.38 ± 47.85  | 4.320 | <0.001***|
|        |        | Obese: 141.22 ± 23.80   |       |         |
|        | 50 cm  | Normal: 186.38 ± 47.64  | 3.161 | 0.005** |
|        |        | Obese: 137.95 ± 27.95   |       |         |
|        | 60 cm  | Normal: 183.27 ± 48.85  | 1.918 | 0.067   |
|        |        | Obese: 148.50 ± 43.47   |       |         |

Values are presented as mean ± standard deviation.

STS, sit to stand; BMI, body mass index; TA, tibialis anterior; RF, rectus femoris; ES, erector spinae.

*P<0.05. **P<0.01. ***P<0.001.
muscle volume, than normal-weight adults (Choi et al., 2015). The results of the present study also showed lower RF muscle activity in obese subjects due to a similar mechanism.

We found differences in ES muscle activity between obese and normal-weight subjects according to chair heights during STS. As previously discussed, obese subjects use the trunk extensor less than normal-weight subjects. Trunk flexion angular velocity increases with progressively lower seat height, indicating that this is an important adaptive strategy for STS motion (Schenkman et al., 1996). Obese subjects require greater trunk flexion velocity than their leaner counterparts at any given chair height (Bollinger et al., 2019). Therefore, compared to normal-weight subjects, obese subjects tend to complete STS with less trunk flexion (Galli et al., 2000; Sibella et al., 2003), thereby minimizing hip joint torque and lower back loading (Sibella et al., 2003). Our results suggest that the lower ES muscle activity observed in obese subjects is similarly caused by lower trunk flexion during STS. Therefore, it is thought that there was a difference compare the muscle activity on the normal weight subjects in the low chair height requiring more trunk flexion angle.

The present study had some limitations. Importantly, the muscle activity data were collected in all phases of STS movement. We also examined only a few lower limb and trunk muscles related to STS movement. Finally, we did not record kinematic data such as joint angle displacement throughout the experiment. Future studies should measure muscle activity in separate phases during STS, collect kinematic data, and include more muscle groups.

In summary, the results of this study demonstrate differences in muscle activity between normal and obese subjects during STS according to chair height. RF and ES muscle activity were lower in obese subjects than in normal-weight subjects at chair heights 40 cm and 50 cm. Previous study reported that obese subjects demonstrated a strategy characterized by limited trunk flexion to minimize the momentum on the lower back at the beginning of the experimental session, whereas at the end of the session, they changed their rising strategy to increase trunk flexion (Galli et al., 2000). Therefore, obese subjects should practice the use of RF and ES muscles in a low-height chair during STS.

**CONFLICT OF INTEREST**

No potential conflict of interest relevant to this article was reported.

**ACKNOWLEDGMENTS**

This work was supported by the Kaya University.

**REFERENCES**

Anandacoomarasamy A, Caterson I, Sambrook P, Fransen M, March L. The impact of obesity on the musculoskeletal system. Int J Obes (Lond) 2008;32:211-222.

Arborelius UP, Wretenberg P, Lindberg F. The effect of armrests and heights on lower-limb joint load and muscular activity during sitting and rising. Ergonomics 1992;35:1377-1391.

Bohannon RW, Barreca SR, Shove ME, Lambert C, Masters LM, Sigouin CS. Documentation of daily sit-to-stand performed by community-dwelling adults. Physiother Theory Pract 2008;24:437-442.

Bollinger LM, Walaszek MC, Sczy RF, Ransom AL. Knee extensor torque and BMI differently relate to sit-to-stand strategies in obesity. Clin Biomech 2019;62:28-33.

Choi SJ, Files DC, Zhang T, Wang ZM, Messi ML, Gregory H, Stone J, Lyles MF, Dhar S, Marsh AP, Nicklas BJ, Delbono O. Intramyocellular lipid and impaired myofiber contraction in normal weight and obese older adults. J Gerontol A Biol Sci Med Sci 2015;71:557-564.

Corrigan D, Bohannon RW. Relationship between knee extension force and stand-up performance in community dwelling elderly women. Arch Phys Med Rehabil 2001;82:1666-1672.

Cuesta-Vargas AI, González-Sanchez M. Differences in muscle activation patterns during sit to stand task among subjects with and without intellectual disability. BioMed Res Int 2013;2013:173148.

de Souza SAF, Faintuch J, Valezi AC, Sant’ Anna AF, Gama-Rodriues JJ, de Batista Fonseca IC, Souza RB, Senhorini RC. Gait cinematic analysis in morbidly obese patients. Obes Surg 2005;15:1238-1242.

Ellis MI, Seedhom BB, Wright V. Forces in the knee joint whilst rising from a seated position. J Biomed Eng 1984;6:113-120.

Fotoohabadi MR, Tully EA, Galea MP. Kinematics of rising from a chair: Image-based analysis of the sagittal hip-spine movement pattern in elderly people who are healthy. Phys Ther 2010;90:561-571.

Galli M, Crivellini M, Sibella F, Montesano A, Bertocco P, Parisio C. Sit-to-stand movement analysis in obese subjects. Int J Obes Ralt Metab Disord 2000;24:1488-1492.

Goulart FR, Valls-Sole J. Patterned electromyographic activity in the sit-to-stand movement. Clin Neurophysiol 1999;110:1634-1640.

Greve J, Alonso A, Bordicini AC, Camanho GL. Correlation between body mass index and postural balance. Clinics(Sao Paulo) 2007;62:717-720.

Hermens HJ, Freriks B, Desselhorst-klug C, Rau G. Development of recommendation for sEMG sensors and sensor placement procedures. J

https://doi.org/10.12965/jer.2040800.400
Electromyog Kinesiol 2000;10:361-374.

Hills AP, Hennig EM, McDonald M, Bar-Or O. Plantar pressure differences between obese and non-obese adults: a biomechanical analysis. Int J Obes Relat Metab Disord 2001;25:1674-1679.

Hilton TN, Tuttle Lj, Bohnert KL, Mueller MJ, Sinacore DR. Excessive adipose tissue infiltration in skeletal muscle in individuals with obesity, diabetes mellitus, and peripheral neuropathy: association with performance and function. Phys Ther 2008;88:1336-1344.

Huffman KD, Sanford BA, Zucker-Levin AR, Williams JL, Mihalko WM. Increased hip abduction in high body mass index subjects during sit-to-stand. Gait Posture 2015;41:640-645.

Jang SY, Ju EY, Park KM, Seo S, Choi SJ, Lee CK, Chun H, Park SW. Association between sleep duration and obesity in young Korean adults. Korean J Obes 2016;25:207-214.

Janssen W, Bussmann J, Selles R, Koudstaal P, Ribbers G, Stam H. Recovery of the sit-to-stand movement after stroke: a longitudinal cohort study. Neurorhabil Neural Repair 2010;24:763-769.

Janssen WG, Bussmann HB, Stam HJ. Determinants of the sit-to-stand movement: a review. Phys Ther 2002;82:866-879.

Kasai T, Kawai K. Quantitative EMG analysis of anticipatory postural adjustments of voluntary contraction of leg muscles in standing man. Electroencephalogr Clin Neurophysiol 1994;93:184-187.

Khemlani MM, Carr JH, Crossbie WJ. Muscle synergies and joint linkages in sit-to-stand under two initial foot positions. Clin Biomech (Bristol, Avon) 1999;14:236-246.

Kim CH. Measurements of adiposity and body composition. Korean J Obes 2016;25:115-120.

Kim SH, Park MJ. Management of childhood obesity. J Korean Med Assoc 2017;60:233-241.

Lomaglio MJ, Eng JJ. Muscle strength and weight-bearing symmetry relate to sit-to-stand performance in individuals with stroke. Gait Posture 2005;22:126-131.

Maffiuletti NA, Jubeau M, Munzinguer U, Bizzini M, Agosti F, Col AD, Lafrontola CL, Sartorio A. Differences in quadriceps muscle strength and fatigue between lean and obese subjects. Eur J Appl Physiol 2007;101:51-59.

Marsh AP, Rejeski WJ, Espeland MA, Miller ME, Shurch TS, Fielding RA, Gill TM, Curalnik JM, Newman AB, Pahor M, LIFE Study Investigators. Muscle strength and BMI as predictors of major mobility disability in the lifestyle interventions and independence for elders pilot (LIFE-P). J Gerontol A Biol Sci Med Sci 2011;66C:1376-1383.

Papa E, Cappozzo A. Sit-to-stand motor strategies investigated in able-bodied young and elderly subjects. J Biomech 2000;33:1113-1122.

Runjhaar J, Koes BW, Clockerts S, Biemra-Zeinstra SMA. A systematic review on changed biomechanics of lower extremities in obese individuals: a possible role in development of osteoarthritis. Obes Rev 2011;12:1071-1082.

Ryan M, Kanthala A, Cantrell A. The prevalence of obesity and obesity-related comorbidities in emergency medicine. Ann Emerg Med 2011;58:S197-S198.

Schenkman M, Riley PO, Pieper C. Sit to stand from progressively lower seat heights-alterations in angular velocity. Clin Biomech 1996;11:153-158.

Sibella F, Galli M, Rimei M, Montesano A, Crivellini M. Biomechanical analysis of sit-to-stand movement in normal and obese subjects. Clin Biomech 2003;18:745-750.

Sipila S, Keskinen SO, Taatje DR, Takala TE, Cheng S, Rantanen T, Toivanen J, Suominen H. Determinants of lower-body muscle power in early postmenopausal women. J Am Geriatr Soc 2004;52:939-944.

Skowronski W, Horvat M, Noepra J, Roswal G, and Croce R. Eurofit special: European fitness battery score variation among individuals with intellectual disabilities. Adapt Phys Act Q 2009;26:54-67.

Teasdale N, Simoneau M, Corbeil P, Handrigan G, Tremblay A, Hue O. Obesity alters balance and movement control. Curr Obes Rep 2013;2:235-240.

Tsios MD, Coates AM, Howe PRC, Grimshaw PN, Walkley J, Shield A, Mallows R, Hills AP, Kagawa M, Shultz S, Buckley JD. Knee extensor strength differences in obese and healthy-weight 10- to 13-year-olds. Eur J Appl Physiol 2013;113:1415-1422.

Visser M, Kritchevsky SB, Goodpaster BH, Newman AB, Nevitt M, Stamm E, Harris TB. Leg muscle mass and composition in relation to lower extremity performance in men and women aged 70 to 79: the health, aging and body composition study. J Am Geriatr Soc 2002;50:897-904.

Walaszek MC, Ransom AL, Capehart S, Pohl MB, Shapiro R, Bollinger LM. External loading alters trunk kinematics and lower extremity muscle activity in a distribution-specific manner during sitting and rising from a chair. J Electromyogr Kinesiol 2017;34:102-108.

Westlake CG, Milner CE, Zhang S, Fitzhugh EC. Do thigh circumference and mass changes alter knee biomechanics during walking? Gait Posture 2013;37:359-362.

Yoshioka S, Nagano A, Hay DC, Fukashiro S. Peak hip and knee joint moments during a sit-to-stand movement are invariant to the change of seat height within the range of low to normal seat height. Biomed Eng Online 2014;13:27.