

9-9-2019

EMG Analysis of the Neuromuscular Activity during Sit-to-Stand from Different Height Chairs in Water

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Recommended Citation

Cuesta-Vargas, Antonio (2019) "EMG Analysis of the Neuromuscular Activity during Sit-to-Stand from Different Height Chairs in Water," *International Journal of Aquatic Research and Education*: Vol. 12: No. 1, Article 6.

DOI: <https://doi.org/10.25035/ijare.12.01.05>

Available at: <https://scholarworks.bgsu.edu/ijare/vol12/iss1/6>

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Abstract

The purpose of this study was to use surface electromyography to measure the muscular activity during the sit-to-stand task in water and compare it at three different chair heights. Ten healthy young adults [5 males and 5 females (mean \pm SD): age, 22.0 ± 3.1 yr; height, 172.8 ± 9.0 cm; body mass, 63.9 ± 17.2 kg] were recruited for study. We used a telemetry EMG system on the following muscles on the right side of the body: quadriceps (vastus medialis and rectus femoris), long head of the biceps femoris, tibialis anterior, gastrocnemius medialis, soleus, rectus abdominis, and erector spinae). Each participant performed the sit-to-stand test five times at each of three different chair heights underwater. No significant differences in muscular activity of all muscles measured during the performance of the sit-to-stand exercise in water were found for any of the chair heights. This study for the first time described the neuromuscular responses in healthy subjects during the performance of the sit-to-stand task in water at different chair heights. The muscular activity of lower limb and trunk should be considered when using the sit-to-stand movement in aquatic rehabilitation.

Keywords: electromyography, aquatic exercise, sit-to-stand test in water

Introduction

Rising from a chair is a prerequisite for participation in many activities of daily living and essential for upright mobility, including walking, jumping, and running (Ploutz-Snyder, Manini, Ploutz-Snyder, & Wolf, 2002). Different determinants of the sit-to-stand (STS) movement have been well described in the literature and they have been classified in three groups, related to the participant, the strategy, and the chair characteristics (Janssen et al., 2002). From all of these determinants, chair seat height is one of the most important (Kerr, White, Mollan, & Baird, 1991) and influences various parameters, like kinematics, performance, or muscular activity (MA). Specifically, it has been shown that MA of lower limb muscles changed when the chair height was modified (Arborelius, Wretenberg, & Lindberg, 1992; Yamada & Demura, 2004). The assessment of STS helps with goal setting and can also form part of a rehabilitation program in the form of a facilitated movement or functional exercise.

Aquatic therapy is beneficial in the management of a variety of neurological, musculoskeletal and cardiopulmonary pathologies (Becker, 2009; Fransen, Nairn, Winstanley, Lam, & Edmonds, 2007; Park, Noh, Kim, Lee, Yang, Lee, et al., 2015; Rahmann, Brauer, & Nitz, 2009). Also, aquatic and closed chain exercises such as steps ups, squats or trunk exercises are used in rehabilitation settings because provides an assisting strategy for people unable to exercise successfully on land (Batterham, Heywood, & Keating, 2011).

Changes in MA in an aquatic setting around the lower limb and trunk have been studied in walking (Barela & Duarte, 2008) (Oliveira, Trócoli, Kanashiro, Braga, & Cyrillo, 2014), trunk exercises (Bressel, Dolny, & Gibbons, 2011), running (Haupenthal, Ruschel, Hubert, de Brito Fontana, & Roesler 2010), hopping (Triplett, Colado, Benavent, Alakhdar, Madera, Gonzalez, & Tella, 2009), and lately during the performance of a STS task (Cuesta-Vargas, Cano-Herrera, & Heywood, 2013). But to the authors' knowledge, the neuromuscular characteristics of the STS movement at different chair heights in water have not previously been described. Because of this, the aim of this study was to use surface electromyography (sEMG) to measure and compare the neuromuscular activity during the STS task in water at three different chair heights (47, 40, and 38 cm) at the same cadence. The hypothesis of the study is that the MA of the measured muscles will be different between the chair heights.

Method

Participants

Ten (10) healthy young adults [five males and five females (mean \pm SD): age, 22.0 ± 3.1 yr; height, 172.8 ± 9.0 cm; weight, 67.8 ± 10.1 kg; Body mass index (BMI), 22.7 ± 1.7] agreed to participate in this study. Research Ethics Committee of the Faculty of Health Sciences from the University of Málaga (Spain) approved the study. All the volunteers were informed about the procedures and gave their written informed consent to join in the study.

During a familiarization session, the subjects were taught the correct technique, as described by Goulart & Valls-Solé (1999); also each participant received verbal feedback from the investigator concerning their posture in the STS task.

Procedures

A telemetry EMG system was used (ME 6000, Mega Electronics Ltd, Kuopio, Finland) on the following muscles on the right side of the body: quadriceps (vastus medialis (VM) and rectus femoris (RF)), long head of the biceps femoris (BF), tibialis anterior (TA), gastrocnemius medialis (GM), soleus (SO), rectus abdominis (RA), and erector spinae (ES). For each muscle, three disposable adhesive circular Ag – AgCl electrodes were located on the belly of the muscle in line of the muscle fibers. Anatomical guidelines for electrode placement were followed (Perotto, Delagi, Lazwetti, & Morrison, 2005; Silvers & Dolny, 2011).

Maximum voluntary isometric contraction (MVC) tests were implemented for estimating the maximal sEMG amplitude for each muscle and a further normalization of the EMG signal (Alberton, Cadore, Pinto, Tartaruga, da Silva, & Krueel, 2011). These MVC tests were carried out on dry land. Each one was implemented for 5 seconds. A waterproof cover was placed on the EMG system and located around the trunk of the subject with a rubber band. After a 15 min. rest interval, participants performed five repetitions of the STS

task inside a swimming pool with a water depth of 100 cm each with the three different chair heights (47, 40, and 38 cm). The starting point was in a sitting position with water at the level of the xiphoid-sternum and the completion of the STS task was in a standing position with water at approximately waist height. The order of execution was maintained for each participant. The same investigator visually determined a correct execution during each repetition without encouragement during the exercise. If the exercise was performed incorrectly, it was repeated after a brief rest period. Participants began each set on the verbal command “go.” The EMG system was manually triggered before the command “go” to record 5 s of data for each set. Water temperature was 30°C and ambient air temperature was 33°C. The transmitting unit was located above the water during all the STS tasks.

The raw electromyographic signal was passed through a 12-bit analog-to-digital converter with a 1000 Hz sampling frequency, and then relocated to a computer for further analysis. Filtering of the raw EMGs was performed with low- and high-pass filters (Butterworth type), with the bandwidth between 20 and 500 Hz. Average EMG data were normalized to the greatest 1-s average EMG during MVC from each muscle.

SPSS v15.0 was used to derive all statistical computations. Descriptive statistics (mean, standard deviation SD), minimum and maximum) were calculated for age, height, and body mass index (BMI). Standard procedures were used to calculate means and SDs. Kolmogorov-Smirnov tests were used to study the central tendency and dispersion of the study variables. Each dependent variable [VM, RF, BF, TA, GM, SO, RA and ES muscle activity (%MVC (%))] was analyzed to compare values between the three chair heights (47, 40, and 38 cm), using a one-way analysis of variance (ANOVA). For all statistical comparisons, the α level was set at 0.05.

Results

The waterproofing appeared to successfully preserve the integrity of the sEMG recordings in all conditions. Descriptive analyses of demographic data of the subjects are presented in Table 1. Kolmogorov-Smirnov tests showed that study variables had a normal distribution.

Table 1. Descriptive analyses of participant information

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Age	10	19	30	22.00	3.091
Height	10	160	187	172.80	9.004
Weight	10	57.5	86.6	67.8	10.1
BMI	10	19.9	24.8	22.670	1.7017

There were no statistically significant differences in % MVC in any muscle during the STS in water between 47, 40, and 38 cm of chair heights (Table 2).

% MVC of VM ($p = 0.85$, $f = 0.16$); RF ($p = 0.98$, $f = 0.02$); BF ($p = 0.91$, $f = 0.09$); TA ($p = 0.96$, $f = 0.04$); GM ($p = 0.93$, $f = 0.08$); RA ($p = 0.91$, $f = 0.09$); ES ($p = 0.86$, $f = 0.16$); and SO ($p = 0.60$, $f = 0.51$).

Table 2. One-way analysis of variance (ANOVA) of % Maximal Voluntary Contraction [MVC] at 47 – 40 – 38 cm chair height.

Muscle	Chair height	Mean	Std. Deviation
RA	47 cm	31,60	29,36
	40 cm	27,00	26,38
	38 cm	28,00	20,57
ES	47 cm	36,20	23,09
	40 cm	31,90	31,64
	38 cm	30,20	17,62
VM	47 cm	1,90	1,20
	40 cm	1,80	1,13
	38 cm	2,10	1,29
RF	47 cm	4,40	9,39
	40 cm	3,70	7,89
	38 cm	4,00	9,16
BF	47 cm	1,20	,42
	40 cm	1,30	,82
	38 cm	1,30	,48
TA	47 cm	5,30	11,93
	40 cm	4,70	9,23
	38 cm	6,10	11,69
GM	47 cm	2,70	2,41
	40 cm	2,30	2,45
	38 cm	2,70	3,06
SO	47 cm	5,50	1,72
	40 cm	5,30	2,00
	38 cm	6,10	1,79

RA = rectus abdominis, ES = erector spinae, VM = quadriceps-vastus medialis, RF = quadriceps – rectus femoris, BF = long head of the biceps femoris, TA = tibialis anterior, GM = gastrocnemius medialis, SO = soleus; Examples of sEMG traces during STS task at three different heights are presented in Fig. 1.

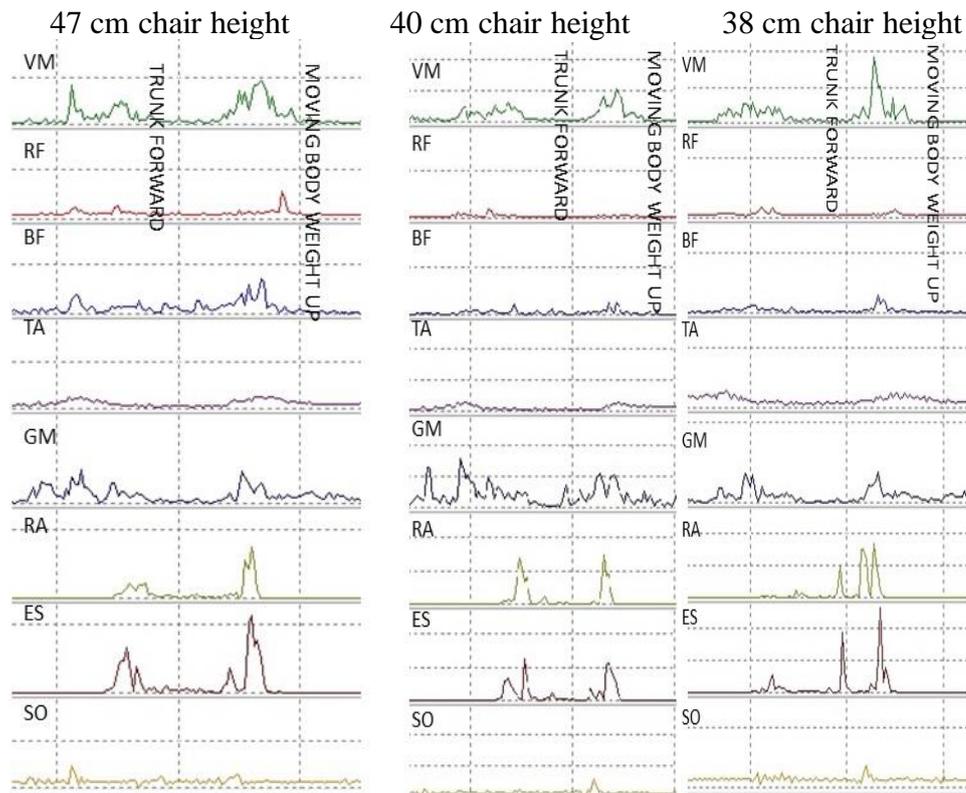


Figure 1 sEMG traces of the same subject during STS task at three different heights. Eight muscles sEMG traces during a STS task from three different chair heights in water. It has been divided in two phases (trunk forward and moving body weight up) in order to illustrate the complete movement.

Discussion

The purpose of this study was to analyze the neuromuscular responses during the performance of an in-water STS exercise using different heights of a chair in an aquatic environment at the same cadences by healthy young adult participants. As far as the authors are aware this is the first study to analyze this functional task in water using different chair heights. The main finding of the present study was that there were no significant differences in MA of any muscles measured (VM, RF, BF, TA, GM, SO, RA and ES) during the performance of the STS exercise in water for any of the chair heights (47, 40, and 38 cm).

There were two recent studies which analyzed the MA of trunk and leg muscles with sEMG during the STS task underwater and on dry land. The first, showed significant differences in MA of both leg and trunk muscles analyzed (VM, RF, BF, TA, GM, SO, RA and ES) between both environments in healthy participants (Cuesta-Vargas et al., 2013). On the other hand, the second study showed differences in MA of RF during the same task between environments in healthy children, but not in children with cerebral palsy (Oliveira et al., 2014).

These results could be explained by buoyancy underwater, which reduces the body weight, facilitates movements, and requires fewer demands of the musculature (Oliveira, Trócoli, Kanashiro, Braga, & Cyrillo, 2014).

There were two previous studies using sEMG data for the study of MA during the performance of a dry land STS . About the activity of TA and RF, the present study showed similar results to one study which showed differences in MA of TA but not for the RF among three groups of healthy young-adults performing the STS task. That study created three groups, divided as lower thigh length longer than 105% of 40 cm, lower thigh length 95% - 105% of 40 cm, and lower thigh length shorter than 95% of 40 cm (Yamada & Demura, 2004). By contrast, while in the present study, the MA of VM and RF were similar on each seat height; in the other study there were differences in MA of vastus lateralis and RF of healthy men performing the STS task with two different chair heights (Arborelius et al., 1992).

Lowering the height of the seat makes the STS movement more demanding or even unsuccessful; these changes can result in changing biomechanical demands or in an altered strategy (Janssen, Bussmann, & Stam, 2002). The findings of these authors were in agreement with some others who had measured performance variables of the STS task on dry land. One study showed that the *five times sit-to-stand test* were significantly longer using the lowest seat (85% knee height) compared with the other two heights, while no differences existed between the medium height and highest seat (100% and 115% knee height) (Ng, Cheung, Lai, Liu, Ieong, & Fong, 2013). Another study using a similar test (*30-second chair stand test*) studied the performance of community-dwelling older adults during the test at a standard height (43 cm) and from five seat heights (from 80% to 120% of each participant's lower leg length) showed that the mean score for standard conditions was significantly lower from higher chairs, but not significantly different between the standard and lower chairs (Kuo, 2013). Subjective ratings of perceived difficulty and safety for both elderly and younger subjects has been studied in both rising and sitting at 80%, 90%, 100%, and 110% to the subject's popliteal (i.e., knee) height, showing that both groups experienced difficulty and poor safety at the lowest chair height (Chen, Lee, Chiou, & Chen, 2010).

Surface EMG in water has been used in research for many years. In the present study, signals from MVC were normalized for each participant in the land condition. Some studies have suggested that dry and underwater conditions influence EMG readings (e.g., Kalpakcioglu, Candir, Bernateck, Gutenbrunner, & Fischer, 2009) which could present inaccurate values for participants in the water condition; other studies looking at sEMG signals with isometric contractions in water and on land have showed that the environment did not significantly influence the sEMG and force in MVC (Castillo-Lozano & Cuesta-Vargas, 2013; Pinto, Liedtke, Alberton, da Silva, Cadore, & Kruehl, 2010).

Limitations

Several limitations about this study should be noted. STS tasks present a lot of determinants that may influence the outcome such as the depth of the water and chair heights independent of the leg length of each participant as well as subject and strategy-related determinants like fatigue or training (Janssen et al., 2002). Future research is required to examine both biomechanical and kinematic data in STS with different seat heights in water as well as combine these data with sEMG data to develop a more comprehensive understanding of this task. Understanding these data could guide aquatic rehabilitation.

Conclusions

In conclusion, rising from a chair is a functional task which has been widely used in aquatic rehabilitation. This study for the first time described the neuromuscular responses in healthy young adult participants during the performance of the STS task in water using different chair heights. The muscle activation of trunk (ES and RA) and lower limb muscles (VM, RF, BF, TA, GM and SO) was similar across chair heights during the performance of the STS movement in water. The results presented in this study could be useful in describing the functional movement of the STS task in water with different chair heights to aid clinical decision making in aquatic rehabilitation programs.

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