UNIVERSITY OF THESSALY

DEPARTMENT OF PHYSICAL EDUCATION AND SPORT SCIENCE

THE DEMANDS OF DAILY LIFE ACTIVITIES RELATIVE TO MAXIMUM CAPACITIES AFTER MUSCLE DAMAGE

Karvouni Evgenia

Supervisor

Giannis Giakas

Μεταπτυχιακή Διατριβή που υποβάλλεται στο καθηγητικό σώμα για τη μερική εκπλήρωση των υποχρεώσεων απόκτησης του μεταπτυχιακού τίτλου του Προγράμματος Μεταπτυχιακών Σπουδών «Άσκηση και Υγεία» του Τμήματος Επιστήμης Φυσικής Αγωγής και Αθλητισμού του Πανεπιστημίου Θεσσαλίας.

Έτος ολοκλήρωσης της διατριβής

2015

Karvouni Evgenia

Department of Physical Education and Sports Science

University of Thessaly

MSc “Exercise and Health”

Karies

Trikala 42100

Abstract

The aim of this study was to investigate the relative effort changes of sit to stand transition (STST) and stand to sit transition (StST) caused by delayed onset muscle soreness (DOMS) and identifying which task is most demanding before and after muscle damage protocol. Ten physically active females, without any musculoskeletal injury or other pathology took part in this study. Eccentric exercise was conducted on an isokinetic dynamometer. Knee joint kinematic and kinetic data were collected via, a 10 camera optoelectronic system. Participants were instructed to perform five StST and five STST efforts. The results have shown that, in both tasks the relative effort is almost the same although the muscle activation and contraction is different.

Key words: StST, STST, relative effort, muscle damage

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Introduction

Sit to stand transition (STST) is sometimes considered as the reverse task of the stand to sit transition (StST). During STST, gravity is opposing the lifting the center of mass and it is achieved mainly by the concentric action of quadriceps. On the other hand, during StST, gravity is forcing the center of mass lower and this fall is mainly regulated by the eccentric action of quadriceps. The inability to perform any of these task can lead to impaired functioning and mobility in activities of daily living (Guralnik, Ferrucci, Simonsick, Salive, & Wallace, 1995; Janssen, Bussmann, & Stam, 2002).

Many researchers have investigated the mechanics of STST and StST in healthy young and elderly people (Akram & McIlroy, 2011; Alexander, Schultz, & Warwick, 1991; Doorenbosch, 1994; Lauziere, Briere, & Nadeau, 2010) (Ganea, Paraschiv-Ionescu, Bula, Rochat, & Aminian, 2011; Leung & Chang, 2009; Mourey, Pozzo, Rouhier-Marcer, & Didier, 1998) as well as in various pathological cases such as stroke (Bohannon, 2007; Chen, Wei, & Chang, 2010; Mazza, Stanhope, Taviani, & Cappozzo, 2006), Parkinson (Bishop, Brunt, Pathare, Ko, & Marjama-Lyons, 2005; Ramsey, Miszko, & Horvat, 2004), hemiplegia (Damiano, 2007; Roy et al., 2007), obesity (Galli et al., 2000; Sibella, Galli, Romei, Montesano, & Crivellini, 2003), osteorthritis and after hip-knee arthroplasty (Houck, Kneiss, Bukata, & Puzas, 2011; Talis et al., 2008; Wang et al., 2006). Despite the large number of studies examining the muscle activity during STST, the research on StST is limited (Ashford & De Souza, 2000; Burnett, Campbell-Kyureghyan, Cerrito, & Quesada, 2011).

Many researchers suggest that muscle weakness and limited strength is the major contributing factor to change the strategy of a movement or to fail accomplishing and lead to fall (Bernardi et al., 2004; Hughes, Myers, & Schenkman, 1996). Apart from aging, muscle weakness can also be followed after fatigue or muscle damage in healthy individuals. Muscle damage is very common to those involved in acute concentric or eccentric muscle contraction after long time of rest. It is important to note that any unaccustomed exercise of high intensity or duration or exercise consisting of lengthening muscular actions (eccentric exercise) induces muscle damage in all ages (Byrne, Twist, & Eston, 2004; Clarkson & Dedrick, 1988). Muscle damage affects the peak joint torque; range of motion (ROM) and 48 hours after it creates delayed onset muscle soreness (DOMS) accompanied with pain (Byrne et al., 2004).

STST and StST like any activity of daily living loads the musculoskeletal system (load) and muscles have to produce adequate force (capacity) for fulfilling the task safely. Thus, a subject-specific load/capacity ratio is created, also referred by some investigators as ‘’relative effort’’, reflecting the demands in every task (Hortobagyi, Mizelle, Beam, & DeVita, 2003; Hughes et al., 1996; Reeves, Spanjaard, Mohagheghi, Baltzopoulos, & Maganaris, 2009). Most researchers have investigated the immediate changes of this ratio by increasing the loading with additional weights (Savelberg et al., 2007; Seven et al., 2008). The capacity in some other studies has been investigated as a function of ageing, disease or artificial muscle weakness (Hughes et al., 1996; Reeves et al., 2009; Spyropoulos, Tsatalas, Tsaopoulos, Sideris, & Giakas, 2013). Thus, any change in relative effort can only be studied with experimental models in healthy young individuals or with long-term studies in elderly. Exercise-induced muscle damage is an experimental model that alters this ratio because the capacity is dramatically decreased (Byrne et al., 2004; Croisier et al., 2003; Spyropoulos et al., 2013) introducing higher stress to the locomotor system and muscle weakness. Hence, the aim of this study was: a) to investigate the relative effort changes of STST and StST caused by DOMS and b) identifying which task is most demanding before and after muscle damage protocol.

Methods

Ten physically active females (25.1 ± 3 years; 165 ± 7 cm; 55.2 ± 5 kg), without any musculoskeletal injury or other pathology volunteered to participate in this study after signing an informed consent form approved by the University's ethics committee. All participants visited the laboratory five times individually within one-week period.

Isokinetic Exercise Protocol and Relative Effort

A 10 min warm up protocol included cycling at 50W (Monark, Sweden) and stretching of the major muscle groups of the lower limbs. Eccentric exercise was conducted on an isokinetic dynamometer (Cybex-Norm, Ronkonkoma, NY). Participants were securely seated at 100° hip flexion angle. The knee ROM was set at 0-100°. Gravitational correction at 45° of knee flexion was also performed. The muscle damage protocol consisted of 5x15 eccentric maximal voluntary actions of the knee flexor and extensor muscle groups in sequence at 60°/s (Tsatalas et al., 2010; Tsatalas et al., 2013). Both legs were exercised randomly in two separate bouts with a 5-min recovery between them and a 3-min rest interval between each of the five sets.

The angle of 70° for maximum isometric knee extension was selected as this angle was found to be very close to the angle of maximum torque during STST and StST after pilot measurements of our sample. The maximal knee joint extension moment during the STST and StST was normalized to the maximum isometric knee extension creating a relative effort ratio for knee extensors.

Muscle damage indices and Data collection

Muscle damage indices (Spyropoulos et al., 2013; Tsatalas et al., 2010; Tsatalas et al., 2013) included average isometric maximum torque at 70° and 30° of knee flexion, measurement of pain through DOMS using a visual analogue scale ranged from 0 (no soreness) to 10 (extremely painful) and creatine kinase (CK).

Knee joint kinematic and kinetic data were collected via, a 10 camera optoelectronic system (Vicon-T40, Oxford, UK), sampling at 100 Hz and a BERTEC (4060-15) forceplate sampling at 1000 Hz. A functional calibration model with 24 retro-reflective markers attached to the pelvis and lower extremities was employed. The position of the markers was marked with permanent pen (lasting 5-7 days) in order to decrease test-retest variability. In this model, the joint centers and axes of rotation are calculated in two stages: static and dynamic. In the static stage, the standard Davis model is used to define the initial position of joint centers and axes of rotation (Davis, Ounpuu, Tyburski, & Gage, 1991). The subject is then asked to rotate the lower limb joints and the new joint positions as well as axes of rotations are refined based on a mathematical optimization procedure (Schwartz & Rozumalski, 2005). Kinetic data were normalized to body mass.

STST and StST tasks

An armless and backless seat fixed at the standard height of 43cm was used for the task. Participants were instructed to perform five StST and STST, triggered with voice at self-selected speed. Hands were crossed on the chest throughout the task and feet were positioned at pelvic width in front of the seat.

Statistics and Data Analysis

Paired t-tests between left and right sides kinematic measurements showed no significant differences. Thus, the right side was used for analysis. The average of five StST trials per subject was used in data analysis. Paired t-tests were used to investigate differences off all kinematic, kinetic and CK measurements pre and 48 hours post exercise. Two-way ANOVA (4 times × 2 muscle groups) was used to analyze DOMS, two-way ANOVA (2 times × 2 tasks) was used to analyze the relative effort and two-way ANOVA (5 times × 2 muscle groups) was used to analyze isometric average peak torque. Significant interactions and main effects were further investigated using Bonferroni post hoc analysis for multiple group comparisons. The level of significance was set to 0.05.

Results

Muscle damage indices

All muscle damage indices altered significantly after the eccentric exercise according to the literature confirming that muscle damage did occur (Table 1). DOMS increased and isometric average peak torque decreased ($p<0.05$) at all-time points. Only 24 hours after the eccentric exercise, knee extensors strength was significantly lower compared to flexors.

StST

The total duration of the task increased significantly by 18% ($p<0.05$). Knee joint initial angle during standing had no significant differences 48 hours after the muscle damage protocol. Maximum knee joint flexion and ROM decreased significantly by 3° and 2.5° respectively ($p<0.05$) (Table 2). Knee joint angular velocity decreased significantly ($p<0.001$) from 135 deg/sec to 102 deg/sec after muscle damage.

STST

After the eccentric exercise protocol, the total duration of STST in absolute time was extended significantly by 15% (Table 2).

Knee extension and flexion were decreased and as a result the knee range of motion had a further decrease (Table 2). The knee joint angular velocity was also decreased from 162 deg/sec to 113 deg/sec ($p<0.001$)

Relative Effort

Before the muscle damage protocol the relative effort needed to execute an StST was 23% of maximum isometric knee joint torque. Forty-eight hours after the exercise the relative effort was 41% (increased by 18%) of the maximum isometric knee joint torque.

Before exercise the STST effort level was 26% while after exercise increased significantly to 42% (increased by 16%) of maximal isometric knee joint moment capability ($p<0.001$).

Table 1. Muscle damage indices ANOVA results, CK paired t-test results. Data are reported as mean (SD).

Muscle Damage Indices	Pre	Immediately after	24 h	48 h
IAPT ext (Nm)	159.6 (28.1)	121.4 (19.4)*	97.5 (33.5)*	91.7 (31.1)*
IAPT flex (Nm)	93 (15.1)	72.2 (12.2)*	66.4 (14.5)*	52.1 (19.1)*
CK (U/I)	180 (119)	NM	NM	NM
DOMS (Knee ext)	0	NM	4.9 (1.5)*	8 (2.1)*
DOMS (Knee flex)	0	NM	4.5 (1.6)*	7.8 (2)*

IAPT ext (Nm): isometric average peak torque absolute values of knee extensors; IAPT flex (Nm): isometric average peak torque absolute values of knee flexors; CK (U/I): creatine kinase; DOMS: delayed onset muscle soreness; NM: not measured;

* Significantly different compared to pre values ($p<0.05$)

Table 2. StST & STST Kinematic and kinetic measurements pre and 48 hours after muscle damage protocol. Paired t-test results (p<. 05*), data are reported as mean (SD).

StST Duration		**Pre**		**Post**		**Sig *(P)***
Total (sec)		1.88	(0.25)	2.21	(0.24)	0.008*
Kinematics						
Knee (deg)	**Min**	2.4	(3.58)	1.42	(6.29)	0.15
	Max	86.87	(5.16)	83.59	(5.12)	0.01*
	ROM	84.47	(9.57)	82.17	(7.88)	0.01*
Kinetics						
Knee	**Moment (N*m/kg)**	0.69	(0.19)	0.63	(0.28)	0.14
Max GRF % of Body Weight		62	(7.2)	60	(7.9)	0.48
STST Duration		**Pre**		**Post**		**Sig *(P)***
Total (sec)		2.53	(0.2)	2.91	(0.58)	0.01*
Kinematics						
Knee (deg)	**Min**	-1.32	(4.73)	1.31	(5.47)	0.04*
	Max	86	(6.1)	83.7	(5.4)	0.03*
	ROM	87.32	(6.71)	82.41	(7.73)	0.005*
Kinetics						
Knee	**Moment (N*m/kg)**	0.77	(0.19)	0.64	(0.21)	0.02*
Max GRF % of Body Weight		64	(7)	60	(9.1)	0.03*

Discussion

In the present study, muscle damage indices altered according to the literature. The duration of both StST and STST were increased due to muscle pain and the reduction of muscle strength capacity. Moreover the slower movement also resulted significant reduction in knee joint angular velocity in both tasks

In StST the maximum knee joint moment and GRF were unaffected 48 hours after the muscle damage protocol. On the other hand the maximum knee joint moment and GRF were significantly reduced. That possibly happened because in StST the eccentric muscle activation is higher than the concentric action in STST. Moreover in STST individuals in pre exercise condition may chose to lift their body with higher muscle strength production than the actual needed strength.

The relative effort needed to execute a StST and a STST pre and 48hours after the exercise was almost the same with no significant statistical differences. In both tasks individuals used almost the same knee joint torque to sit and standing up pre and after the exercise however the maximum isometric knee joint torque at the same knee joint angle were dramatically decreased. Thus the relative effort increased significantly in StST and STST after the muscle damage mostly due to the significant reduction of the maximum strength capacity. Our results are similar to those reported to the literature and show that any reduction of muscle strength affects the relative effort even in simple tasks of daily living.

Conclusion

Our study shows that in both tasks the relative effort is almost the same although the muscle activation and contraction is different. Those results could be helpful in rehabilitation of individuals with movement difficulties due to aging or other pathology.

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