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GLUTEUS MEDIUS AND THIGH MUSCLES ELECTROMYOGRAPHY DURING LOAD CARRYING WALKING

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ABSTRACT

This study compares the electromyographic (EMG) peak amplitude changes of gluteus medius (Gmed), vastus medialis (VMO), vastus lateralis (VL) and biceps femoris (BF) during load carrying walking due to the increased load. The percentage of maximum isometric voluntary contractions (%MVIC) of both limbs and 3D kinematic of lower limbs were detected on eighteen resistance-trained men (mean age \pm SD, 31 \pm 3.4 years) while carrying loads of 25, 50 and 75% of their body mass (BM). The repeated measurement ANOVA was used to evaluate the differences in muscles %MVIC and 3D kinematics at all load conditions. Significant differences were found for Gmed %MVIC ($F_{3,99} = 19.8, p < 0.001$). Gmed activity was significantly different between load carrying walking with 25% of BM (mean \pm SD, 20 \pm 12%MVIC), 50% of BM (32 \pm 17%MVIC) and 75% of BM (45 \pm 26%MVIC) condition. Differences were found in hip flexion at Gmed EMG peak ($F_{3,96} = 14, p < 0.001$), between 25% of BM (18 \pm 11°) and 50% of BM (29 \pm 7°). No significant differences were found for thigh muscles, when thigh muscle activity did not exceed 30%MVIC even at 75% of BM condition. Load carrying walking is an exercise which activates Gmed more than thigh muscles. This exercise increases the Gmed activity along with increased loads and it should be regarded as a complex Gmed strengthening exercise. This exercise is recommended for strengthening the Gmed with low activation of VL and VMO.

Keywords: Electromyography; MVIC; Farmer's Walk; strength training; vastus lateralis; vastus medialis

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INTRODUCTION

The performance and safety during strength exercises is in close relationship with individual muscle activity. Malfunction of the gluteus medius (Gmed) has been associated with low back pain (Nadler et al., 2001; Bolgia & Uhl, 2005), hip instability (O'Sullivan et al., 2010;

Noh et al., 2012; Pandey et al., 2010) and other pathologies (Powers, 2003; Kim et al., 2012). Another important issue of muscle involvement is the activation of vastus medialis obliquus (VMO) and vastus lateralis (VL) to knee joint stability (Irish et al., 2010), where VMO weakness or activity delay toward VL action is associated with internal knee rotation and anterior cruciate ligament injury (Bennell et al., 2010; Crossley et al., 2001; Van Tiggelen et al., 2009; Cowan et al., 2001). Strong or early accelerated VL activity is associated as a compensation of VMO weakness. This muscle imbalance can be expressed as a VMO/VL EMG ratio (Irish et al., 2010). VMO, VL and Gmed muscles participate in the complex of medio-lateral stabilization at one limb stance (Baffa et al., 2012; Felício et al., 2011; Crossley et al., 2001). If the hip lacks stability during single limb activities, the femur may adduct and internally rotate, which changes the muscle involvement and kinematics in knee joint area (Krause et al., 2009; Reiman et al., 2009; Crossley et al., 2001). Thus the Gmed weakness influences the movements and VMO/VL action in the knee joint, where both muscle group functions are related to each other.

For strength training, it would be optimal to find an exercise which favours the activation of VMO and Gmed during complex movement. Complex exercises could bring a stimulating effect for muscle involvement in more than just one joint and improves inter-muscular coordination. Even more appropriate, would be an exercise which targets Gmed and also stimulates the balance in between VMO and VL. VMO activity during exercises has been evaluated in many studies (Herrington & Pearson, 2006; Cerny, 1995; Stastny et al., 2014), where exercises like lunge or squat with thigh adduction favours the VMO activity (Felício et al., 2011; Irish et al., 2010). On the other hand there are studies, in which this effect on similar exercises was not proven (Baffa et al., 2012). Previous research focused on Gmed (Bolglia & Uhl, 2005; Distefano et al., 2009) determined the most appropriate exercises to strengthen the gluteal muscles according to their role. Most of the previous studies were performed with exercises used in physiotherapy, whose effect summarises the Boren (Boren et al., 2011) and Reiman (Reiman et al., 2012) study. The highest electromyography (EMG) values were during side plank abduction, single limb squat, hip clam, progression and front plank with hip extension, which are exercises usually performed without an external load.

Typical physiotherapeutic exercises are rather isolated and weight bearing, than complex with external loads, where complex exercises are considered to be more effective for strength training in athletes and the general population. Most studies (Reiman et al., 2012; Herrington & Pearson, 2006; Selkowitz et al., 2013; Boren et al., 2011) have evaluated the exercise in weight bearing conditions, but the issue of muscle action could vary due to the exercise intensity (Siff, 2003; Stastny et al., 2014). For strength training it is important to choose the exercise which has the expected muscle involvement in weight bearing conditions as well as in external load conditions.

A movement with a well identified muscle activation pattern in a weight bearing condition is walking (Ivanenko et al., 2004; Winter et al., 1990; Pandey et al., 2010), where the walking pattern can be used as a complex exercise in strength training. One kind of this application is a load carrying walk called the "Farmer's Walk", which is a commonly performed strongman exercise used in a general strongman training session (Winwood et al., 2011). Load carrying walking is also used as condition test for ageing men for its movement simplicity (Holviala et al., 2010). Farmer's Walk is an exercise which includes lateral hip and knee stability, which is related to the action of Gmed, VMO, VL and BF.

PURPOSE

Complex exercises such as squats, lunges, Farmer's Walk or step ups can be performed with individual techniques variation, where their evaluation needs the exact description of each exercise variety. This exercise variability requires a kinematic evaluation of performed movement, because there is the possibility of muscle involvement changes due to kinematic changes. The aim of this study was to evaluate the kinematic variables and muscle activity caused by increased loads during the Farmer's Walk, to decide if this exercise leads to increasing the VMO or Gmed action along with increased load. The assumption before this experiment was, that increasing the carried load during the Farmer's Walk would activate Gmed and VMO more than VL and BF.

METHODS

Participants

The research group consisted of 18 symptom free individuals (mean \pm SD, age 31 ± 3.4 years, body mass 88 ± 8 kg, squat performance 120 ± 20 kg) actually performing the strength training program at the minimal amount of three lower extremity training sessions per week. All participants had at least 5 years of experience with the strength training. Participants were informed about the testing protocol and all aspects of the study when they signed the contract with the study. The testing protocol was approved by the local Committee of Ethics in accordance with the ethical standards of the Helsinki declaration of 1983.

Procedure

The warm up procedure included 5 minutes of cycling and sets of 25 squats in 5 different foot positions following the EMG taping and maximal isometric performance. After isometric tests, the participants were taped with the 3D markers to performed five trials of 8 m walking. Between trials at each loading condition were rest intervals from 30 to 60 s and 2–3 min between loading condition. Short rest interval between trials was used because no loads did reach individual repetition maximum for 8 m, but sufficient rest interval was used between loading conditions (the sets) according to American Society of Exercise Physiology (Brown & Weir, 2001). Participants were instructed to walk carrying dumbbells with shoulder retraction, but with no instruction for lower limbs (preferring natural performance).

Surface EMG activity of Gmed, VMO, VL and BF was measured bilaterally while participants performed four load conditions of walking: walking with just their own body mass (BM), load-carrying walking with 25%, 50% and 75% of BM (25BM, 50BM, 75BM). The subjects carried pairs of dumbbells with the total of prescribed weight on 8 m detection walkway. The dumbbell hand was taped with sticky rubber to avoid slipping. Surface EMG was measured along with 3D kinematics of walking to detect the knee joint and hip joint angles. EMG data was normalized to each participant's peak task maximal isometric voluntary contraction (MVIC), where MVIC was determined by standard positions on

dynamometer IsoMed. This study was done in cross sectional design, where loading conditions were independent variables and muscle activity with kinematics dependent variables.

EMG

Raw EMG signals of all muscles were collected with the Noraxon Myosystem 1400A device (Noraxon; Scottsdale). The signal was recorded by eight leads with 1000 Hz frequency. Two bipolar surface electrodes (adhesive disposable electrode – Kendall, Masfield, MA, USA) were placed with a 10 mm inter-electrode distance. Input impedance was greater than 10 M Ω at 100 Hz. The raw signal was transferred using an analogue signal connection to the 3D system (Vicon data log via MX box). The raw signal was simultaneously operated by the program MyoResearch XP Master Version 1.03.05.

EMG data was band-pass filtered (50–500 Hz), and smoothed using a root mean square followed by a window frame envelope with time constant 200/25 ms. The EMG signal was normalized to the maximum EMG value from isokinetic tests to %MVIC. The maximum amplitude (peak) was chosen to describe the maximal level of muscle activation, where the peak was recognized from 25 ms using the sliding mean method Fig. 2.

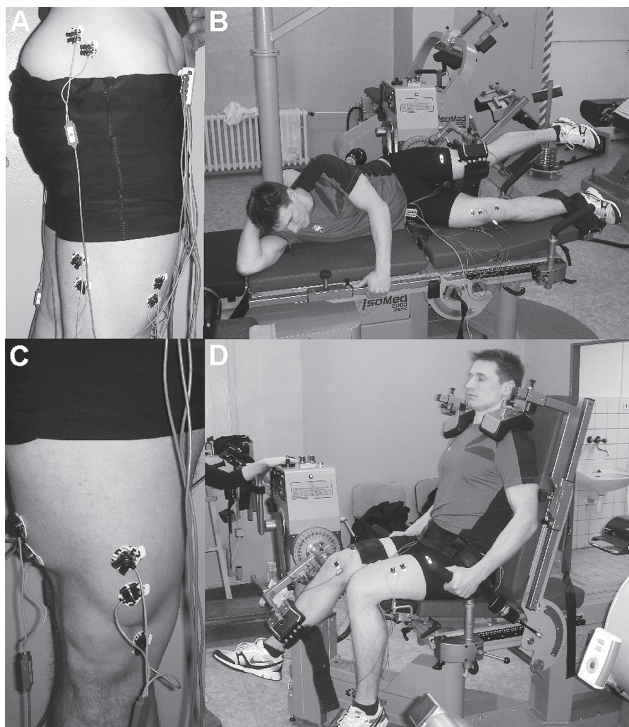


Figure 1. Detail of EMG electrodes placement and body position during maximum voluntary isometric contraction (MVIC). A) Gluteus medius (Gmed), biceps femoral (BF) and vastus lateralis (VL) EMG placement. C) Vastus medialis obliquus (VMO) EMG placement. B) A body position during Gmed MVIC. D) A body position during BF, VMO and VL MVIC.

The electrodes for VMO were placed over the distal third of the muscle belly and were oriented 55° to the vertical (Fig. 1). The electrode for VL was placed over the muscle belly in distal third and it was oriented 15° to vertical (Gilleard et al., 1998). Gmed was located by palpating the iliac crest and placing electrodes parallel to the muscle fibres in 33% of the distance between the iliac crest and greater trochanter (Bolglia & Uhl, 2005; Bolglia & Uhl, 2007), which is similar to those used by O'Sullivan (O'Sullivan et al., 2010) for Gmed posterior part (Fig. 1). The electrodes for biceps femoral were placed over the distal third of long head muscle belly Fig. 1. The ground electrode was placed over the tibia bone.

Maximal isometric voluntary contraction measurement

The normalized EMG used “angle specific MVIC” method (Isometric-spec MVIC) (Burden, 2010). Where the subjects performed 5 s isometric contraction two times on dynamometer IsoMed 2000 (D & R Ferstl GmbH, Hemau, Germany). VMO, VL and BF MVIC were performed in a sitting position at 75° of knee flexion. The backrest of dynamometer seat was set to an angle of 75°, the angle in the hip joint was 100°. Participants were fixed by belts in the pelvic and thigh region on tested lower limbs. Adjustable straps and pads were placed at the shoulders and participants held hand grips along the seats Fig. 1. The mechanical axis of the dynamometer was aligned with the knee's axis of rotation utilizing the lateral femoral epicondyle as a bony reference. The distal shin pad of the dynamometer lever arm was attached 2 cm proximal to the medial malleolus at a position of 90° knee flexion by using a strap.

Gmed reference values for MVIC was done two times in standard muscle testing positions for gluteus medius with the measured lower extremity in 15° of hip abduction Fig. 1. The tested leg was fixed in dynamometer by straps and dynamometer kept the testing position of the leg. Before executing the maximal isometric contraction, a full range of motion was performed on the dynamometer. The axis of the dynamometer was aligned with the greater trochanter on the femur, the arm of the dynamometer lever was fixed to the lateral thigh tested limb, 1 cm above the patella.

Kinematics

Kinematic data was recorded at 100 Hz using a six-camera Vicon MX infrared motion analysis system (Oxford Metrics, Oxford, UK). Cameras were spaced around the walking track with two force plates (Kistler Instrumente, Winterthur, Switzerland) in the middle. Force plates were connected to Vicon software via MX box. Participants' pelvises and both legs were fitted with reflective markers (14 mm diameter) secured to anatomical locations by an experienced physiotherapist. Markers were attached on the subject to the skin overlying the following landmarks: anterior superior iliac spine, posterior superior iliac spine, lateral thigh, lateral femoral epicondyles, lateral tibia, lateral malleolus, heels, second metatarsal head.

The gait cycle was computed from heel to heel contact of each lower limb. Heel strike was assessed on the force plate where the vertical force achieved 20 N. This process allows the exact determination of the walking pattern for every individual. From each

attempt, for analyses, one gait cycle of right and left leg were chosen with detected data from EMG, 3D analyses and force plates. For each measured condition 5 fully detected execution of walking patterns were performed for statistical analyses.

Data acquisition

Kinematic and EMG data was collected simultaneously by Vicon Neux software, in the case where the data was corrupted, it was discarded from the data collection. EMG was also discounted if the amplitude did not show periodicity during the following steps. EMG peak amplitude was expressed as %MVIC for Gmed, VMO, VL and BF ($Gmed_{\%MVIC}$, $VMO_{\%MVIC}$, $VL_{\%MVIC}$, $BF_{\%MVIC}$). Kinematic data was normalized for the gait (step) cycle as in Winter study (Winter et al., 1990) separately for both legs and was expressed where peak value occur during percentage of gait cycle or joint position at EMG peak (Fig. 2). Expressed values were: gait cycle at Gmed peak ($Gmed_{GC}$), gait cycle at VMO peak (VMO_{GC}), gait cycle at VL peak (VL_{GC}), gait cycle at BF peak (BF_{GC}), knee flexion at peak value of VMO, VL or BF (VMO_{flx} , VL_{flx} , BF_{flx}) and hip flexion at Gmed peak value ($Gmed_{flx}$).

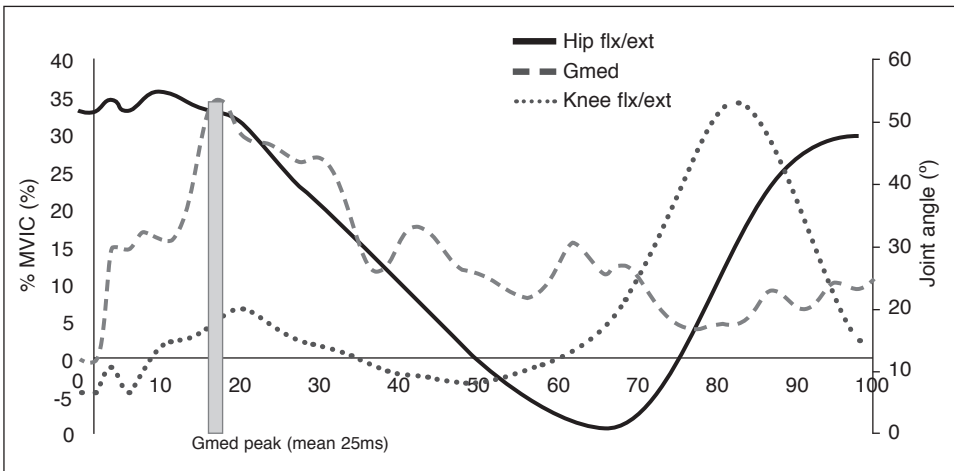


Figure 2. EMG peak value for Gmed and related kinematic data. Gluteus medius (Gmed), maximum voluntary isometric contraction (MVIC), flexion (flx), extension (ext). Gmed peak was counted from 25 ms sliding mean.

Statistical Analyses

The reliability across 3 trials of each individual loading condition was counted by an individual single case intraclass correlation coefficient (ICCs) on confidence interval 0.95 to confirm if EMG measurement is stable within a subject (Portney & Watkins, 1993). A repeated-measure analysis of variance (ANOVA) was used to compare if selected parameters such as $Gmed_{\%MVIC}$, $VMO_{\%MVIC}$, $VL_{\%MVIC}$, $BF_{\%MVIC}$ showed significant differences in measured loading conditions. Tukey post hoc test was used to find a setting

of significant differences. STATISTICA version 12 (StatSoft, Inc., Tulsa, OK, USA) software was used for statistical analysis. Statistical significance was set at $p < 0.05$.

RESULTS

The single measured reliability analysis expressed as a ICCs ranged from 0.63 to 0.86 for $Gmed_{\%MVIC}$, which is considered to be between moderate and high level of reliability (Chandler & Brown, 2008; Chinn & Burney, 1987). Standard error of measurement (SEM) for $Gmed_{\%MVIC}$ slightly increased from 1.44 to 4.80, which means that individual differences were increased along with the increased load (Tab. 1). The ICCs for $Gmed_{GC}$ and $Gmed_{flx}$ ranged from 0.40 to 0.90.

Table 1. Test reliability of observed parameters at confidence interval 95%

		Gmed		VM		VL		BF	
		ICCs	SEM	ICCs	SEM	ICCs	SEM	ICCs	SEM
%MVIC	BM	0.86	1.44	0.83	4.77	0.94	3.36	0.70	0.91
	25BM	0.63	2.23	0.89	5.17	0.67	2.33	0.40	0.73
	50BM	0.72	3.02	0.88	5.37	0.73	3.99	0.64	0.87
	75BM	0.84	4.81	0.48	3.13	0.71	1.90	0.81	0.94
%GC	BM	0.90	2.74	0.50	3.78	0.64	2.54	0.58	0.85
	25BM	0.84	2.77	0.44	3.58	0.68	2.42	0.57	0.84
	50BM	0.41	1.58	0.39	2.66	0.75	3.25	0.31	0.64
	75BM	0.64	1.20	0.74	3.11	0.70	1.74	0.59	0.85
Hip flx* Knee flx**	BM	0.78	1.38	0.58	1.49	0.68	1.54	0.25	0.57
	25BM	0.40	1.97	0.48	1.59	0.42	1.31	0.53	0.81
	50BM	0.44	1.25	0.36	1.81	0.37	1.34	0.58	0.85
	75BM	0.66	1.53	0.58	0.96	0.48	1.52	0.63	0.87

Legend: Gmed = gluteus medius; VMO = vastus medialis obliquus; VL = vastus lateralis; BF = biceps femoris; ICCi = individual intraclass correlation coefficient; ICCm = mean intraclass correlation coefficient; SEM = standard error of measurement; BM = body mass; %MVIC = percentage of maximal voluntary isometric contraction; %GC = percentage of gait cycle; flx = flexion; * hip flexion value in Gmed case; ** knee flexion value in VMO, VL, BF case; LC = loading condition

The ICCs for VMO_{flx} , VL_{flx} and BF_{flx} showed low reliability in cases of BF_{flx} (ICCs = 0.36 and VL_{flx} (ICCs = 0.37) at 50BM condition, then for BF_{GC} (ICCs = 0.39) and VM_{GC} (ICCs = 0.31) at the load condition of 50BM, which means that kinematic data at EMG peak were not stable in these cases (Tab. 1). The lowest ICCs was found in VM_{GC} (ICCs = 0.25). The reliability of EMG data was in general more stable than the kinematic data.

Table 2. Basic characteristic for all parameters and loading condition

	Gmed (Mean ± SD)			VMO (Mean ± SD)			VL (Mean ± SD)			BF (Mean ± SD)		
	%MVIC (%)	Flx (°)	%GC (%)	%MVIC (%)	Flx (°)	%GC (%)	%MVIC (%)	Flx (°)	%GC (%)	%MVIC (%)	Flx (°)	%GC (%)
BM	15 ± 8	19 ± 8	23 ± 15	16 ± 16	14 ± 8	23 ± 15	17 ± 18	15 ± 8	25 ± 14	24 ± 26	13 ± 8	40 ± 21
25BM	19 ± 12*	18 ± 11*	14 ± 15	18 ± 10	18 ± 8	29 ± 14	21 ± 13	16 ± 7	21 ± 13	30 ± 28	17 ± 9	44 ± 20
50BM	32 ± 7*	29 ± 7*	11 ± 9	17 ± 10	15 ± 8	21 ± 14	23 ± 22	16 ± 7	23 ± 18	29 ± 29	16 ± 10	39 ± 15
75BM	45 ± 25*	27 ± 8	12 ± 6	17 ± 8	14 ± 10	21 ± 13	21 ± 10	12 ± 8	17 ± 9	30 ± 17	11 ± 5	34 ± 16

Legend: %MVIC = percentage of maximal voluntary isometric contraction; %GC = percentage of gait cycle; flx = flexion; Gmed = gluteus medius; VMO = vastus medialis obliquus; VL = vastus lateralis; BF = biceps femoris; BM = body mass; SD = standard deviation; n = 36; * significant difference for dependent variable

The EMG variability of parameters was high at BM loading condition for $VM_{\%MVIC}$ (mean ± SD, 16 ± 16), $VL_{\%MVIC}$ (17 ± 18) and $BF_{\%MVIC}$ (24 ± 26) (Tab. 2), which was not observed in $Gmed_{\%MVIC}$ (15 ± 8) at unloaded condition. High variability was also found in $BF_{\%MVIC}$ at 25BM (30 ± 28) and 50BM (29 ± 29) see Tab. 2.

Significant differences were found between $Gmed_{\%MVIC}$ ($F_{3,99} = 20, p < 0.001$) Fig. 3 and Tab. 3. Gmed activity was significantly greater in load carrying walking with 25BM (mean ± SD, 20 ± 12 %MVIC), 50BM (32 ± 17 %MVIC) and 75BM (45 ± 26 %MVIC) condition Fig. 3. The BM condition (15 ± 8 %MVIC) differs from 25BM condition, but without statistical significance Fig. 3.

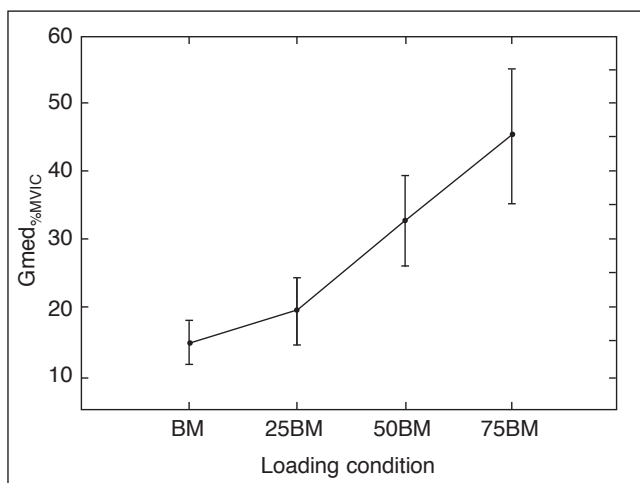


Figure 3. Repeated measures ANOVA results for $Gmed_{\%MVIC}$. Peak Gmed value in MVIC ($Gmed_{\%MVIC}$), percentage of maximal voluntary isometric contraction (%MVIC). Body mass condition (BM), 25% body mass condition (25BM), 50% body mass condition (50BM), 75% body mass condition (75BM). Current effect: $F_{3,99} = 20, p < 0.001, 0.95$ confidence interval

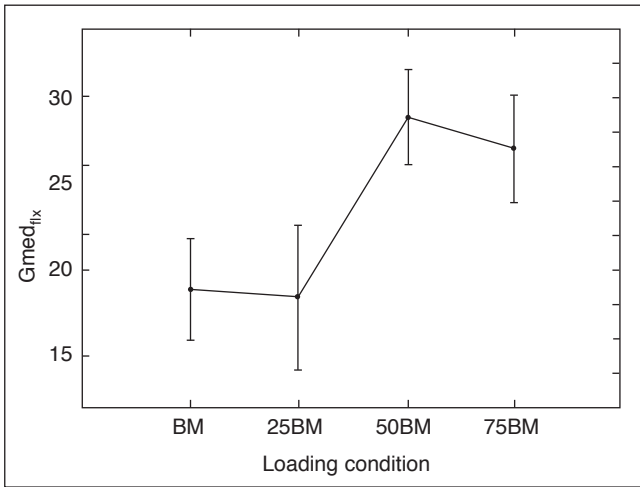


Figure 4. Repeated measures ANOVA result for Gmed_{flex}. Hip flexion at Gmed EMG peak value (Gmed_{flex}). Body mass condition (BM), 25% body mass condition (25BM), 50% body mass condition (50BM), 75% body mass condition (75BM). Current effect: $F_{3,96} = 14$, $p < 0001$, 0.95 confidence interval

Significant differences were found in Gmed_{flex} ($F_{3,96} = 14$, $p < 0.001$), where post hoc tests show differences between 25BM (mean ± SD, 18 ± 11°) and 50BM (mean ± SD, 29 ± 7°) Fig. 4 and Tab. 3. No significant differences were found for thigh muscles, when thigh muscle activity did not exceed 30% MVIC even at 75BM condition.

Table 3. Repeated measures ANOVA results for observed parameters*

	F	P	HSD	Power α
Gmed _{%MVIC}	19.83	0.0001	11.96	0.91
BF _{%MVIC}	0.55	0.6503	13.87	0.15
VM _{%MVIC}	0.23	0.8745	6.80	0.09
VL _{%MVIC}	0.94	0.425	9.30	0.24
Gmed _{GC}	5.76	0.0013	8.50	0.94
BF _{GC}	1.19	0.3187	13.23	0.30
VMO _{GC}	3.20	0.0251	8.30	0.73
VL _{GC}	2.76	0.05	8.84	0.64
Gmed _{flex}	14.00	0.0001	5.66	0.87
BF _{flex}	3.54	0.0181	5.45	0.76
VM _{flex}	3.96	0.0370	5.70	0.68
VL _{flex}	2.43	0.07	6.10	0.58

Legend: %MVIC = percentage of maximal voluntary isometric contraction; GC = gait cycle; flex = flexion; F = F value; Gmed = gluteus medius; VMO = vastus medialis obliquus; VL = vastus lateralis; BF = biceps femoris; HSD = honestly significant difference (Tukey)

DISCUSSION

Load carrying walking was found to be an exercise activating the Gmed, where the carried load is increased. This exercise targets the Gmed more than thigh muscles, because thigh muscles do not significantly change the level of activity along with increased load. The potential benefit of load carrying walking, is in strengthening the gluteal muscles, but with marginal effect on VMO strengthening, at least in trained individuals. Gmed increased its activity due to the increased load, but also due to the hip flexion where Gmed peak was observed. Gmed peak activity was reached at a greater degree of hip flexion at 50BM and 75BM (28°, 29°) than BM and 50BM (18°, 19°). This finding is in agreement with previous work (O'Sullivan et al., 2010), where hip flexion/extension corresponds to a higher level of Gmed posterior work.

Load carrying walking did not show as a high level of activation (above 60% MVIC) in weight bearing condition as an exercise such as side lying hip abduction (Distefano et al., 2009), single limb squat (Distefano et al., 2009) or side bridge to neutral spine position (Ekstrom et al., 2007) where Gmed activity was even lower than thigh muscle activity. In the 75BM condition the Gmed activity increased up to 45% MVIC which is comparable activation to the transverse lunge (Distefano et al., 2009), wall squat (Ayotte, 2007), lateral step up (Ekstrom et al., 2007) or unilateral mini squat (Ayotte, 2007) in weigh bearing conditions.

In general the 21–40% MVIC is considered to be a moderate level of activation (Reiman et al., 2012), which was reached already in the 25BM condition. The 40–60% MVIC is considered to be a high level of activation (Reiman et al., 2012), this level was reached at the 75BM condition. Above 40% MVIC is also a minimal activity level needed for strength gain for the Gmed (Ayotte, 2007; Reiman et al., 2012). Although the muscle activation varies with each individual's training level, if this amount is achieved in experienced individuals, there is a presumption of even higher activation in untrained individuals. Beyond that, the external load can be add even more, until the exercise technique is disrupted.

In the case of increasing the carried load to the maximum, it would be appropriate to check if the Gmed activity is not exceeded by tensor fascia lata activity as it was measured in the Clam exercise (McBeth et al., 2012). This aspect of the exercise was not held in this study because of the focus on thigh muscles, but further assessment that load carrying walking is a primary target for Gmed more than tensor fascia lata, as in hip abduction (McBeth et al., 2012), squats or sidesteps (Selkowitz et al., 2013), is needed.

Load carrying walking is a complex exercise, which is used in daily activity where this movement pattern can influence the stability of walking itself. This statement should be used when load carrying walking is applied in the common population. Since this movement is used as the Farmer's Walk event during strongman competitions, and strongman training (Winwood et al., 2011), these results suggest that the Farmer's Walk performance can be improved by strengthening the gluteal muscles rather than the thigh muscles (beyond the grip strength). Application of load carrying walking as a general condition test (Holviala et al., 2010) appears to be reasonable, because the Gmed action influences complex body coordination such as hip to knee stability and low back pathologies. So the relevance of this test is as a complex movement provided by important primal mover and stabilizer.

Kinematics during the step cycle show a similar course of Gmed during all load conditions (Fig. 3), which was the same as in studies focused on the walking pattern itself (Winter et al., 1990; Arendt-Nielsen & Sinkjær, 1991; Pandy & Andriacchi, 2010). A similar course of EMG activity was found compared to previous studies (Winter, 1991; Bird et al., 2003; Ivanenko et al., 2004), where Gmed peak was observed during the landing phase of the step cycle. The timing of Gmed peak was observed during the landing phase of the step cycle. The timing of Gmed peak activation in the gait cycle was slightly accelerated, but without any statistical significance.

A standard testing protocol was used to determine the Gmed MVIC, where body position was similar, as in the previous study (Widler et al., 2009). The difference was in using a standardized dynamometer in which the tested leg is connected to the resistant level by straps, which bring a position of comfort as is recommended (Kramer et al., 1991). The participant referred a high comfort level in dynamometer especially when the preparation movement was performed by testing equipment. This testing comfort could increase the detected Gmed peak value, which could decrease the detected %MVIC.

The limits of this study are in the EMG peak amplitude usage, because there can be qualitative differences to the mean EMG value. Peak EMG value was chosen because the peak task could be a better reference to the strength maximum and also for the ability of the peak task to compare the timing of peak activation. This would be more complicated by using the mean task EMG. Another limit of this study is the EMG response for selected load, which can vary between the individuals due to the genetics profile (Petr et al., 2014) or type of exercise (Čoh & Žvan, 2011).

Result of this study showed that the amount of carried weight changed the relative muscle activity in primal movers, where this change can modified the strengthening effect of exercise. This assessment should be done for every weight bearing exercise which showed to involve muscles such as VMO, Gmed, abdominals and others.

CONCLUSION

Load carrying walking (Farmer's Walk) is an exercise which activates Gmed more than thigh muscles. This exercise increased the Gmed activity along with increased load and it should be regarded as a complex Gmed strengthening exercise. This exercise is recommended for strengthening the gluteal muscles with relatively low activation of VL and VMO. Amount of carried weight changes the relative muscle activity in primal movers, which can modify the strengthening effect of the exercise. Therefore, the recommendations for individual muscles strengthening should include both the selection of exercise and its intensity expressed in amount of relative load.

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