Effect of acute fatigue in the muscles of the medial longitudinal arch on jump height

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Abstract

Eight male athletes participated in a study of fatigue with the purpose of investigating the effect, acute fatigue in the muscles of the medial longitudinal arch (MLA) has on jump height. The participants performed a control experiment with no fatigue, and an intervention where they were fatigued in the muscles of the MLA by performing a short foot fatiguing exercise. Maximal voluntary isometric contractions (MVIC) of five seconds were used as a measurement of fatigue with the help of a force platform. A Pre and post measurement of maximal vertical jump height was performed, using the impulse method. We hypothesized that fatigue in the muscles of the MLA would reduce jump height. According to the MVIC measurements, fatigue was only significant in the intervention ($p = 0.0002$) and a students paired t-test ($p = 0.53$) indicated no significant difference in vertical jump height from pre to post fatigue.

Introduction

Many investigations have been made, concerning the primary muscles that contribute to jumping performance. Jump itself is not difficult, but to jump high is a complex task that requires both strength and technique. The primary contributing muscles for power generation during jump are the gluteus maximus, the hamstrings, rectus femoris, vasti, soleus, gastrocnemius and the Tibialis anterior (Pandy & Zajac, 1991; Anderson,1993). In addition, Pandy & Zajac (1991) wanted to find the optimal muscle coordination during a jump by using a dynamical model (Pandy, 1990), measuring force and EMG and observed that the muscles contributing to jump must be activated at a given time to generate the movement pattern that makes a person jump high. Futhermore, Pandy & Zajac (1991) found that the main energy contributors during a squat jump is gluteus maximus and vasti, but also saw a tendency that the participants performed a minor countermovement when they were told to perform a maximal squat jump. As supplemental knowledge, Grégoire et al. (1984) found that energy is transported, from the proximal to distal joints during a countermovement jump. Furthermore jumping induces stretch shortening cycle in the tendons of the lower limb muscles. During stretch-shortening cycle exercises, the energy is stored in tendon structures when the muscle is lengthening and is reused when its shortening (Kubo et al.,2007; Komi, 2000).

By observing a countermovement jump, where the ankles are plantarflexed, the toes are dorsal flexed and the muscles of the MLA (Abductor Hallucis, Flexor Hallucis brevis, quadriceps plantae and the flexor digitorum brevis) are stretched just before take-off, the muscles of the MLA could have an effect on jump height. The effect the muscles of MLA has on jump height has not previously been studied, and it is therefore unknown if fatigue of these muscles has an effect on jump height. Bobbert et al. (2011) has shown that fatigue in the ankle plantar flexor muscles, also known as the extrinsic foot muscles, can reduce the maximal vertical jump height by approximately 6 cm using a dynamometer.

Earlier articles have described the possibilities of fatiguing the MLA muscle abductor Hallucis.Headlee et al. (2006), who wanted to assess the effect of intrinsic foot muscle fatigue on pronation, found that a voluntary isotonic contraction exercise, where the participants used their toes to pull down a weight that was attached to a rope which went through a top fixed pulleywheel, were useful in fatiguing the MLA, since they saw a reduced electromyographic (EMG) activity of the abductor hallucis and a navicular drop, due to fatigue. Furthermore, Fiolkowski (2003) anesthetized the tibial nerve and found a similar decrease in EMG activity and a navicular drop.

In extend, Jung et al. (2010) found, by comparing the short foot exercise, where the calcaneus and the metatarsal bone was placed on the ground and the foot was shortened in an anterior-posterior direction without flexing the toes, produced a significantly higher EMG activity (45.2% ± 18: percentage of MVIC) in the abductor hallucis compared to the toe-curls (10.1% ± 5.5: 45.2% ± 18: percentage of MVIC) where the participants curled their toes with an interphalangeal and metatarsophalangeal flexion of the toes.

We recently completed a similar pilot study, to compare the voluntary isotonic contraction exercise used by Headlee et al. (2006) with the voluntary short foot exercise used by Jung et al. (2010). The exercises were compared, in order to determine which one was the most effective in fatiguing the abductor hallucis. The participants performed the isotonic contraction exercise and the short foot exercise the same day with the same EMG electrodes on abductor hallucis, soleus and lateral gastrocnemius. This was done to avoid the risk of misplacing the EMG electrodes between exercises. We found the short foot exercise to be the most effective. (To be reported in another paper).

To the best of our knowledge, the effect fatigue in the MLA muscles has on jump height has not previously been studied, like Pandy & Zajac (1991) and Anderson & Pandy (1993) who did not mention any effects of the muscles in the MLA on jump height despite measuring on a plantar flexion. We find it doubtful that the muscles of the MLA has no effect on jump height, since Grégoire et al. (1984) predicted a proximal-to-distal muscle activation in a vertical countermovement jump and that the MLA muscles are the last contact point before take-off. We therefore hypothesize that fatigue of the muscles in the MLA leads to a reduction in a maximal vertical jump. The purpose of this study was to determine if fatigue of the muscles in the MLA have an effect on maximal vertical jump height.

Method

A within participant design was used in this experiment (Leedy & Ormrod, 2010).

The independent variable was MVIC force output at four levels of state, pre-and post in both the control and intervention in the muscles of the MLA and the dependant variable was vertical jump height.

Participants

8 healthy male participants (age = 24.00±2.71 years; Body mass = 75.2±7.5 kg) who all where active in sports including jumping or running, participated in the experiment. The participants self-reported no history of fractures or diseases that could influence the lower extremities or foot. Neither had they had any history of trauma or pain in the lower extremities, the foot, or in the lumbosacral part of the back, 12 months before the experiment. Furthermore, the participants had no visible sign of hallux valgus, hallux limitus/rigidus, claw toes or hammertoes.

The participants signed a written informed consent before participating in the experiment.

Information concerning the experiment was sent to the participants, one week before the experiment, *by email*, containing the written consent and videos, pictures and explanations of the exercises and how to perform them. The purpose of this information was to distribute information to the participants and thereby shortening the teaching and correction phase of the participants in the given exercises on the day of the experiment.

Procedure

The experiment consisted of a control- and an interventional part. Besides sending information about the different exercises at least one week before the experiment, the participants went through a thorough review of each exercise on the given day of the experiment to make sure the exercises was correctly executed. Before beginning the protocol, a dynamic warm up was performed since this has proven to be beneficial by Turki et al. (2011). The warm-up consisted of two parts. The first part was a five minute run on a treadmill at a self selected speed. Secondary the participants went through five different dynamic stretching exercises including, easy skip, backward run, walking diagonal lunges and straight leg strides (Perrier et al., 2011 - table 2). The dynamic warm-up was carried out for approximately 10 minutes. Following the warm-up, 10 minutes of EMG electrode placement was carried out for measurement of EMG activity during the experiment (to be reportet in another paper), followed by trial jumps and MVIC to test the equipment for functionality. When the warm up and the trials were completed the data collecting began.

Exercises

The following section explains the exercises used in the experiment to obtain the measuring parameters.

Figure 1 - Tape markings on the two forceplatforms, with five centimeters between each marking.

<u>Maximal vertical jump</u> was performed on the two force plates with the feet on each of the platforms (Bobbert et al., 2011). The platform was marked with tape to make sure the participants were placed with the same width of the feet in each jump (figure 1). The tape was placed with five centimeters between each piece of tape. When the participants got familiar with the width of the feet they found most natural in a vertical jump, three maximal vertical jumps were performed with their hands placed just above the hips, with 10 seconds of rest between each jump (Voigt et. al, 1994). It was the highest of the three jumps that was used in the further data processing (Galazoulas et al., 2011).

Calculation of jump height

To calculate jump height, the following equation is suggested by Andersen & Kristensen (2011) but a similar method was used by Moir (2008) and Street et al. (2001).

$$h = \frac{v^2}{g \cdot 2}$$

Where, h= jump height (m), v=velocity (m/s) and g = gravitational acceleration (9.82 m $\cdot$ s^{-2}). To use this equation, the velocity must be found with the following.

$$v_{takeoff} = \sum_{t_{start}}^{t_{takeoff}} \frac{F_{FP} - F_g}{m} \cdot \Delta t$$

Where: $v_{takeoff}$ = Velocity at takeoff (m/s), $t_{takeoff}$ = instant the feet leaves the forceplatforms, t_{start} = start of the countermovement, F_{FP} = Vertical ground reaction force (N), F_g = Force with no movement (N) - average of first 2 seconds, m = Body mass of the participant (kg) and Δt = sample duration (1/sampling frequency (s)).

The start of the countermovement were identified by calculating the peak residual from the force with no movement during the 2 seconds of quiet stance (peak difference between the force with no movement and the subject's body weight) and the take-off was identified by the first value beneath the calculated peak residual.

Figure 2 - The MVIC experimental setup (the MVIC block is seen from the top). The feet were fixed with straps and the toes placed on the MVIC platform.

<u>Maximal voluntary isometric contraction (MVIC)</u> was executed sitting in a chair with the ankles and knees in an angle of 90 degrees (Jung et al., 2010). The feet was placed on the short foot platform with the toes sticking out and placed on the MVIC block, which was placed on the force platform (figure 2). Furthermore the participants had their feet secured with straps (Headlee et al., 2006). The fixation was marked with a pen on the short foot platform, the medial part of the metatarsal bone and the cuneiform bone. In that way, the mark on the short foot platform and metatarsal bone would always be aligned as with the mark on the cuneiform bone and the fixation strops was also aligned, to secure the same settings in every MVIC.

The participants were instructed to push their toes downwards without bending them, since this has proved to produce activity in the muscles of the MLA (Headlee et al., 2006; Jam, 2006). During the MVIC it was emphasized that the participants were not allowed to lift their heels and only contract the muscles of the MLA to minimize muscle activation in the leg muscles. The participants were encouraged verbally during the MVIC to ensure optimal motivation. The MVIC was used, to measure whether the participants produced less force after the short foot fatiguing exercise, and therefore was fatigued (Taylor et al., 2000; Taylor & Gandevia, 2007; Vøllestad, 1997).

Measuring fatigue
The MVIC force reduction was measured during the experiment to ensure fatigue of the participants before the last vertical jumps. Peak was found in each of the three MVIC and the highest was selected for further analysis. The fatigue was calculated as the percentage change between the two highest peak values, pre and post. (Colombo et al., 2000; Aboordarda et al., 2011).

<u>Short foot fatiguing exercise</u> was used to fatigue the muscles of MLA. The participants were seated in a chair with their feet on the short foot fatiguing exercise platform. The participants were told to shorten the MLA in an anterior-posterior direction, while keeping the calcaneus and the metatarsal bone in the ground. The participants contracted the muscles of the MLA following a metronome that beeped with one second intervals, meaning that they were to maximally contract the muscles of the MLA for one second and relax for one second (Kawakami, 2000).(figure 3).

Protocol

The protocol is schematically illustrated in figure 4 and 5.

Figure 3 - The short foot fatiguing exercise. The muscles of the MLA is contracted on the left picture while relaxed on the right. The short foot fatiguing exercise platform is seen from the top.

Control (Figure 4)
The control was used to make sure the participants did not reduce their jump-height only due to fatigue induced by the jumps and MVIC and to have documentation suggesting that a possible reduction was not a coincidence. The control was performed approximately five minutes before and the same way as the intervention, but with five minutes of rest instead of the short foot fatiguing exercise. Specifically, the control consisted of three maximal vertical jump(Pre jump) with 10 seconds of rest between each jump, three MVIC with 10 seconds of rest between each MVIC, five minutes of restitution, three MVIC with 10 seconds of rest between each MVIC and three maximal vertical jump (post jump) with 10 seconds of rest between each jump. The Control experiment was carried out over a period of approximately ten minutes.

Following the control, a five minute break was carried out before the intervention was executed. It was not found to be necessary with more than five minutes of rest since Bobbert et al. (2011) has suggested that a break of 150 seconds is enough to recover from a fatigued calf muscle. In addition Woods and Bigland-Ritchie (1987) explored the effect MVIC has on quadriceps by measuring force, motor unit firing rate (Hz) and voluntary muscle activation. A reduction was seen in all measuring parameters after 40 seconds of MVIC. When the muscle was held ischemic (with an inflated cuff) at the end of the 40 seconds of MVIC, the force, motor unit firing rate (Hz) and voluntary muscle activation were kept low despite three minutes of rest. In opposition when the cuff was removed from the muscle and blood flow was possible, the muscle was able to nearly recover within 3 minutes.

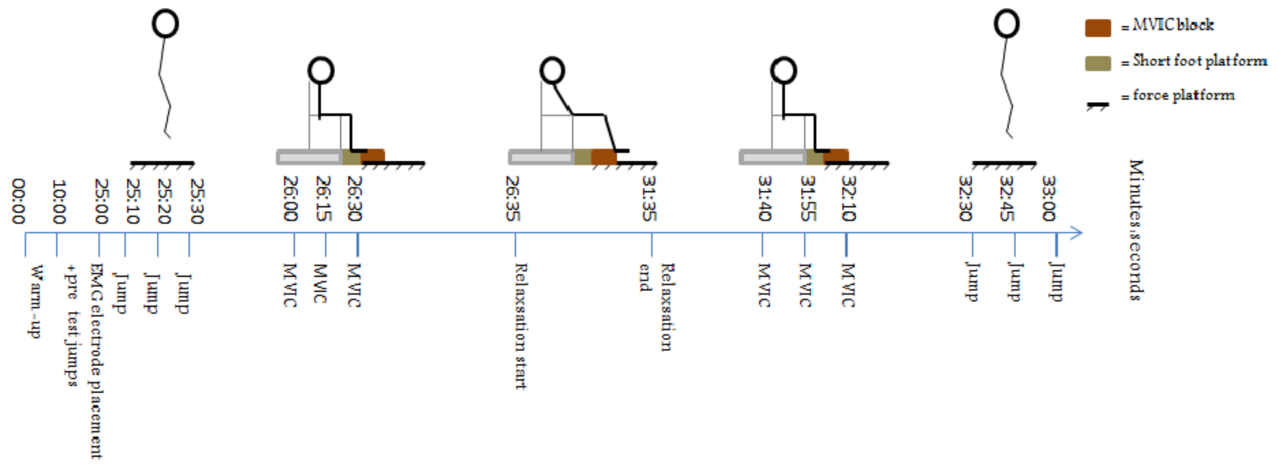

Figure 4 - The control experiment with time estimations. The MVIC block was placed on the force platform and used for the MVIC and the short foot platform was placed behind the MVIC block and was also used for MVIC (figure 2). The force platform was used for jumping and the MVIC (Figure 1; figure 2).

Intervention (figure 5)

The purpose of the intervention was to investigate if fatigue of the muscles in the MLA would change the maximal vertical jump height. The participants performed three maximal vertical jumps with ten seconds of rest between each jump. Secondly the participants performed three MVIC with 10 seconds of rest between each MVIC. Since the participants were not fatigued in the first three MVIC, the peak MVIC force output generated in those was considered to be the highest possible the participants could generate. Following the MVIC a short foot fatiguing exercise period began of 10 minutes to begin with which was followed by three MVIC and immediately two minutes of extra short foot fatiguing exercise (Fatigue evaluation period). The two minutes of short foot fatiguing exercise was used by the investigators to calculate if the participants had generated a smaller peak force output in the MVIC and therefore was fatigued. The short foot fatiguing exercise, MVIC and calculation minutes was repeated if the participant was not fatigue, but with a reduction of two minutes in the short foot fatiguing exercise. (see figure 5).

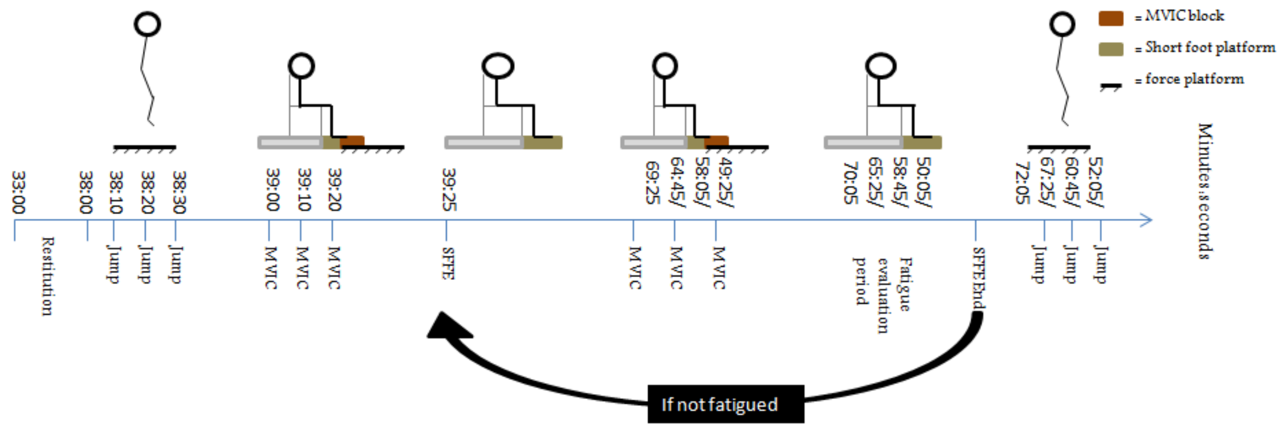

Figure 5 - The intervention with time estimations. SFFE = Short foot fatiguing exercise. The MVIC block was placed on the force platform and used for the MVIC (Figure 2). The short foot platform was used for the short foot fatiguing exercise and the MVIC (figure 2; figure 3). The fatigue evaluation period was the two minutes of of extra short foot fatiguing exercise for calculating fatigue.

Instrumentation

Ground reaction force was measured using two BERTEC force platforms (1881, COW PLATE) standing beside each other. These platforms were used for measuring ground reaction forces during the maximal vertical jump and for measuring the force during the MVIC.

The analog signals from the force platforms went through a sampling box (National instruments - BNC-2090) and further on to a computer with an A/D-converter plugged in. The computer had the LabVIEW (National instruments) based data acquisition software, Mr. Kick installed. The force platform data was sampled with 2000 Hz as suggested by Street et al. (2001) and displayed in Mr. Kick in Newton (N). Secondary the data was stored on a computer disk.

Data processing was done in both MATLAB (MathWorks) and Microsoft office excel (home edition 2007). During the experiment, the investigators used MATLAB to acquire the specific measures which was exportet to Excel for calculation of MVIC force reduction. Furthermore MATLAB and Excel were used in the further processing, such as calculation of changes in jump height, after the experiment.

A custom build short foot fatiguing exercise platform was constructed (Figure 2; figure 3). The platform consisted of two long wooden piles, for extra weight, with a wooden plate on top of them. Holes were cropped in the wooden plate so straps could be tightened and fixation of the feet was possible. Furthermore a MVIC block was made, with a wooden pile in the middle and two wooden plates on each side of the wooden pile to make sure it was stable (figure 2). The short foot platform was used in the short foot fatiguing exercise and the MVIC, and the MVIC block was used only for the MVIC. Both short foot fatiguing exercise and MVIC will be described in the following section.

Statistics

A Students paired t-test was used to determine differences between the groups. Statistical significance was set at $P \leq 0.05$.

Results

The initial results indicated that a break of 5 minutes during the control contribute to a reduction in jump height (p = 0.005). All of the participants had a reduction in jump height during five minutes of break (-1.08 ± 0.76). (Table 1B). At the same time the students paired t-test indicated that there were no significant difference between the jump height from pre short foot fatiguing exercise to post short foot fatiguing exercise (p = 0.53).

Table 1B shows no significant difference between the change in jump height, in the control compared to the intervention (p = 0.34). There were no correlation between fatigue percentage and change in jump height for both the control and intervention (control r = -0.27; intervention r = -0.33).

Table 1A shows the force output generated during the MVIC exercises in all of the participants. No significant difference were found in the MVIC force output during the control(p = 0.16). A significant difference (p = 0.0002) in MVIC force output of the intervention were found.

MVIC force output (N) – A						
	Control			Intervention		
	Pre	Post	Change (%)	Pre	Post	Change (%)
Participant 1	449.99	376.01	-16.4	297.17	272.84	-8.2
Participant 2	668.02	579.44	-13.3	556.08	473.35	-14.9
Participant 3	514.23	309.82	-39.8	387.69	329.29	-15.1
Participant 4	512.28	578.47	12.9	566.79	455.83	-19.6
Participant 5	542.46	522.01	-3.8	477.24	358.49	-24.9
Participant 6	481.13	474.32	-1.4	424.68	312.74	-26.36
Participant 7	309.82	321.5	3.8	405.21	277.7	-10.33
Participant 8	326.37	290.36	-11	340	263.1	-29.23
Average	475,53	431.49	-8.6	431.86	342.92	-18.9
SD	116.36	121.55	15.8	96.35	81.62	7.7
Students paired t-test (Pre → post)	P = 0.16			P = 0.0002*		

Jumpheight (cm) – B						
	Pre	Post	Change (Δ)	Pre	Post	Change (Δ)
Participant 1	22.8	21.9	-0.9	20.5	20.5	0.1
Participant 2	37.2	36	-1.2	31.5	33.7	2.2
Participant 3	34.5	33.9	-0.5	33	31.2	-1.7
Participant 4	34.1	33.6	-0.5	38.8	38.2	-0.5
Participant 5	27.6	25.6	-2	24.6	24.3	-0.4
Participant 6	40.5	38.2	-2.3	39.3	40	0.7
Participant 7	30.6	29.5	-1.1	31.7	28.1	-3.5
Participant 8	24.2	24.1	-0.1	21	21.2	0.2
Average	31.44	30.35	-1.08	30.05	29.65	-0.36
SD	6.26	5.98	0.76	7.35	7.42	1.69
Students paired t-test (Pre → post)	P = 0.005*			P = 0.53		
Students Paired t-Test Δ Change jumpheight (Control → intervention	**P = 0.34**					

Table 1 - A: The MVIC force output from pre to post in both the control and intervention and the change observed in the MVIC (%). Pre: Highest peak force output of the first three MVIC performed. Post: Highest peak force output of the last three MVIC perfomed. B: The jumpheight pre and post in the control and intervention and the change observed (CM). * = significance of p-value ≤ 0.05.

The amount of time performing the short foot fatiguing exercise is illustrated in table 2.

There is no correlation between numbers of MVIC performed and the change in jump height (r = -0.057) and neither is there any correlation between the minutes of short foot fatiguing exercise performed and the change in jump height (r = -0.115).

	SFFE (min)	Number of MVIC
Participant 1	26	12
Participant 2	12	6
Participant 3	12	6
Participant 4	26	12
Participant 5	12	6
Participant 6	12	6
Participant 7	20	9
Participant 8	30	15

Table 2 - SFFE (min): Minutes of short foot fatiguing - exercise performed during the intervention.
MVIC: The MVIC performed during the intervention.

Discussion

The primary finding of this study was that acute fatigue in the muscles of the medial longitudinal arch did not induce a decrease in jump height. The students t-test indicated that the muscles of the MLA do not contribute to a vertical jump which is inconsistent with the hypothesis. The jumps performed in the control produced a significant reduction in jump height in contrary to the jumps in the intervention. Due to a lack of significant difference, it cannot be concluded that the decrease in jumps is caused by fatigue in the muscles of the medial longitudinal arch. This statement is supported by the reduction in jump heights for the control. Therefore it must be another factor causing the reduction in jump height.

The results obtained in this experiment was a contradiction to Bobbert et al.(2011) who observed a decrease in jump height of approximately 6 cm due to fatigue in the ankle plantarflexors of the right leg. This reduction, however, was obtained by fatigue of all ankle plantar flexor muscles in contrast to our study where only the plantar intrinsic foot muscles were fatigued.

The information to the participants facilitated the work of the investigators when teaching the subjects the exercises. The amount of time consumed in teaching varied depending on the participants' preparations before attending the investigation.

Instruction of the participants gave them an understanding of how the exercises should be implemented and furthermore the investigators observed the foot during the short foot fatiguing exercise. Due to these observations it is believed that the short foot fatiguing exercise was performed correctly in all subjects.

We aimed to minimize contractions, of other muscles than the ones of the medial longitudinal arch that contributes to maximal vertical jump. According to Kawakami & Fukunaka (1998) and Kawakami et al. (2000), the gastrocnemii are contributing less to an ankle plantar flexion when the knees are flexed in an angle of 90 degrees compared to fully extended knees. This distinction between the knee angle affects on produced ankle joint plantar flexion joint is caused by the biarticular structure of the gastrocnemius which crosses the knee joint. Therefore, the fascicle length of gastrocnemius and its contribution to plantar flexion torque are affected by knee joint angle (Kawakami, 2000). Furthermore, the metatarsal joint are primarily flexed by the intrinsic foot muscles, the lumbricals and flexor digitorum brevis (Jam, 2006).This may suggest that the short foot fatiguing exercise is not affecting the triceps surae as much as the MLA muscles. It is likely that neither the gastrocnemii nor the soleus muscle is fatigued since the MVIC performed in this experiment is constructed for fatigue of the muscles of MLA unlike the MVIC of Kawakami & Funaka (1998) and Kawakami et al. (2000) that was constructed for fatigue of the triceps surae.

Jam (2006) who suggest that performing the short foot fatiguing exercise with stiff toes pushing down instead of rolling the toes, activates the MLA muscles instead of the extrinsic foot muscles, thereby support that the short foot fatiguing exercise is not fatiguing the triceps surae muscles. In addition, Bobbert et al. (2011) found a reduction in jump height of six centimeters after fatiguing the plantar flexors. A reduction of less than two centimeters in our experiment indicates a smaller amount of fatigue in the extrinsic ankle plantar flexors compared to Bobbert et al. (2011).

Our assessment of fatigue was done according to Headlee et al. (2006). In addition, Jung et al. (2011) suggested that the MVIC used in this experiment, activates the muscles of the MLA the same way as in the short foot exercise. To support this, it was found by the researchers of this experiment that the AH is active during the MVIC (unpublished data from a pilot study performed by the researchers). The fatigue of the muscles in the MLA was found as a reduction in MVIC force output, which is described as the "gold standard", but it is also suggested to use electrical stimulation in order to identify the location of fatigue (Vøllestand, 1997). Therefore, the method used for measuring fatigue in the medial longitudinal arch is found to be valid and furthermore found to be transferable to jump since it activates the muscles in the same manner as when the toes leaves the ground in jumping (Pandy & Zajac, 1991).

Jump height was calculated according to both Andersen & Kristensen (2011) and Moir (2008). During the calculation the investigators were aware of the limitations attached to the impulse method suggested by Street et al. (2001). Street et al. (2001) suggested that sampling of force platform data should be above 1000 Hz when measuring jump height, but due to EMG sampling (to report in another paper) it was chosen to sample with 2000 Hz (Hart et al., 2006a; b; Zijdewind et al., 1998). Therefore, the sample frequency insinuated no errors in calculating the jump height.

On the other hand the establishment of the countermovement start and take-off were highly influenced by the participants' standing-phase prior to the jump (Street et al., 2001). The participants were emphasized to stand still during the standing-phase before the jump to minimize chances of calculation differences between jumps when establishing the start of the countermovement and the take-off.

If any possible errors, in the establishment of the start of the countermovement and the take-off, were included, they are the same throughout the experiment due to the unidirectionality of the measuring methods and it is therefore still possible to compare the results within the subjects.

All participants reduced their jump height during the control while only half reduced the jump height in the intervention. The review of Fradkin (2010) has shown that warm up of 3-10 minutes improved performance in 79% of the occasions it was done. Furthermore Girard et al. (2009) investigated whether aerobic running, athletic drill and sprint warm-up were producing different results on maximal voluntary contraction torque, muscle activation and shortening time of a contraction, than strength based warm-up consisting of back squat, olympic lifting movements and reactivity exercises. Girard et al. (2009) found no difference in maximal voluntary contraction torque, muscle activation and shortening time between the two warm-up protocols. Instead he found that maximal voluntary contraction and muscle activation increased more than 10% while shortening time of the muscles was reduced more than 11% in both groups. This was in relation with the findings of Pearce (2012) that observed a reduction in muscle conduction time post to warm-up and furthermore found that warm-up is effective in increasing the chemical reactions in the muscles and thereby prepare the participants for activity. Galazoulas et al. (2011) suggest that performance in countermovement jumps, following a 27 minute warm-up including a general, dynamic and a sports specific part would decline in less than ten minutes of break and then gradually decline for every ten minute until the measuring stopped after 40 minutes. As earlier mentioned in the procedure, EMG electrode placement was executed (to report in another paper) for 10 minutes after the warm up, which might have caused cold muscles, but due to the following test jumps (5 minutes) it could be that the participants was warm when starting the control protocol. In contrary, it is possible that the five minutes of break in the control could have caused cold muscles before the post- MVIC and jump, since Galazoulas et al. (2011) also suggested that body temperature declines following 10 minutes of rest. An active break could have resolved the issue of cold muscles. Mohr (2004) indicated that a passive break of 15 minutes during halftime in a football game, decreased sprinting performance with 2,4% whereas an active break where the participants performed 7 minutes of relaxation followed by 7 minutes of running at 70% of maximum heart rate, kept sprinting performance unchanged. This shows that an active break would have been beneficial.

It is a possibility that the triceps surae was activated during the MVIC, but due to the fixation and the placement of the foot the risk of transferring force generated with the triceps surae is minimized. To avoid activity in the triceps surae, the participants were emphasized to relax in their leg muscles, trunk and keep the heel in the ground during the MVIC.

Kawakami (2000) showed that a plantarflexion MVIC of one second intervals needed to be executed 40 times with one second of rest between each MVIC before a significant decrease in peak torque could be observed. Even though the MVIC length was shorter but more frequent, it could indicate that the triceps surae was not fatigued.

Fatigue of the muscles could have been transferred from the control to the intervention. Woods and Bigland-Ritchie (1987) has shown that fatigue induced by MVIC should be nearly recovered within three minutes. In contrary, Nicol & Komi (2006) has shown 1-2 hours of exercise recovery from stretch shortening cycle fatigue was needed to recover the muscle tendon stiffness. It might be possible, that the eccentric phase during a countermovement could have carried fatigue from the control to the intervention since Horita et al. (2003) suggests that the eccentric phase in a dynamic movement is fatiguing. However, table 1 indicates that there were no carryover of fatigue from the control post to the intervention pre in the average MVIC force and jump height.

Conclusive remarks

Fatigue was induced. This had no effect on jump height.

Odd results showed a reduction in jump height in the control.

Recommendations

To definitely remove any suspicions of carryover fatigue, the control and intervention could have been performed at separate days and furthermore by performing a cross over study. Aboodarda (2011) used a cross-over study design with three weeks between tests, to avoid any carryover effect between exercises, when testing the effects of two different strength training systems. This would make it possible to tell more about the possibility that fatigue induced by the control was affecting the intervention. Furthermore, these changes in the protocol would have shown whether the reduction found in the control was due to jump itself or because the participants were cold following the break. If the method used in this protocol was to work, a warm up before the control and intervention could have been beneficial. To sustain the effects of the warm up, an active break could have been used (Mohr, 2004)

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