The effect of different accentuated eccentric load levels in eccentric-concentric loading contractions on acute neuromuscular, growth hormone and blood lactate responses during a hypertrophic protocol

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ABSTRACT

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When accentuated load is applied during the eccentric (ECC) phase of eccentric-concentric (ECC-CON) contractions, it is defined as dynamic accentuated external resistance (DAER) exercise. This study monitored acute neuromuscular responses, growth hormone (GH) and blood lactate (La) concentrations to find out the most efficient ECC-CON loading strategy for muscle hypertrophy by employing various DAER resistances in the bench-press. Male subjects (age=32.4±4.3years, n=11) were assigned as subjects. The measurements consisted of 4 "hypertrophic" sessions separated by 5-6 days recovery. The subjects performed 4 sets of 10 repetitions with 2 min recovery between the sets. The resistances were 70%, 80%, 90% and 100% of 1 RM for the ECC phase and 70% RM was constantly used for the CON phase. Muscle EMG, growth hormone (GH) and blood lactate (La) were measured at pre and post conditions in ISOM bench press and EMG was measured also in the 2^{nd} (pre) and last (post) repetitions in dynamic measurements. ECC force was systematically smaller in the 70% condition than in the other conditions (P<0.001). Significant reductions in ISOM pre to post peak force occurred in all conditions (P<0.01-0.001). CON force reduced from pre to post loading in all conditions (P<0.001). Pre to post change in La in the 90% condition (9.5±2.3mmol/l) was greater (P<0.05) than in the 70% condition (7.7±1.1mmol/l). The highest individual pre to post change in La was larger after the 90% (p<0.001) condition compared to La after the control condition. No significant differences were observed in absolute mean post GH and in GH/repetition concentrations between the conditions. ECC EMG of the agonists increased with the increase in load but was significant only in deltoid anterior (P<0.01). A significant relationship (P<0.05) was observed between optimal ECC load and 1RM/bodymass-ratio (R=0.85). The major findings in the present study were the higher change of La in the 90% condition compared to the 70% condition (P< 0.05) and the high correlation between the optimal ECC load and 1RM/BM-ratio. The findings can be applied into practice in designing optimal exercise protocols in training for muscle hypertrophy and suggest the importance of individualised load selection for DAER exercises.

Key words: DAER, dynamic accentuated external resistance, strength

LIST OF ABBREVIATIONS

BM	Body mass
CIR	Circumference
CON	Concentric action on muscular level
DAER	Dynamic accentuated external resistance
DCER	Dynamic constant external resistance
ECC	Eccentric action on the muscular level
ECC %1RM	Eccentric load defined by percentage concentric 1RM
EMG	Electromyography
EO	Eccentric overloading
FT	Free testosterone
GH	Growth hormone
ISOM	Isometric
La	Lactate
MU	Motor unit
MVC	Maximum voluntary contraction
PRE	Perceived rate of exertion
RFD	Rate of force development
RM	Concentric repetition maximum
ROM	Used limb range of motion
SSC	Stretch-shortening cycle
ST	Standard training
T	Testosterone
VL	Vastus lateralis

CONTENTS

pages

1 INTRODUCTION

Eccentric exercise has been associated with a greater mechanical efficiency compared to CON exercise (Enoka, 1996), despite of concurrent lower neuromuscular activation (figure 1). ECC actions are also associated with greater neuromuscular adaptations and hypertrophic increases compared to concentric actions as were suggested by Farthing and Chilibeck (2003); Hortobagyi *et al.* (1997). Similarly, ECC-CON muscle contractions are associated in some of the studies such as Dudley et al. (1991), Hather *et al.* (1991), Häkkinen and Komi (1981) mainly to provide greater development in neuromuscular strength than independent CON or ECC actions only. Linnamo *et al.* (2003) discussed a selective MU recruitment to be potential explanation behind the greater force production relative to the rate of activation in ECC action compared to CON. There could be expected to occur alternative options behind the enhanced force generation, such as an alteration in the crossbridge detachment mechanism and improvement in contractile activity by improved release of Ca^{2+} due to stretch of less completely activated sarcomeres. In addition, number of other studies have suggested additional ECC stimulus to cause enhanced increases in hypertrophy such as in the studies of Hortobagyi *et al.* (1997) and Andersen *et al.* (2005), or alternatively, ECC stimulus has enhanced maximum force generation as was found in the studies of Doan *et al.* (2002); Hortobagyi *et al.* (2001); Brandenburg and Docherty (2002).

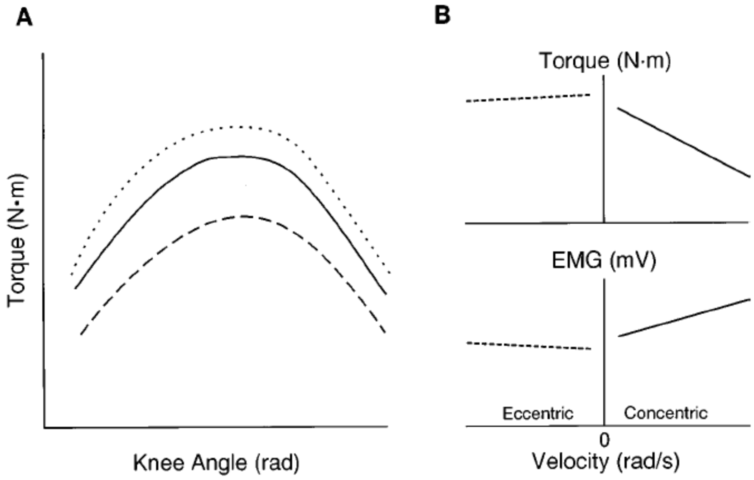

FIGURE 1. Evidence of greater force generation during ECC compared to CON with same (or lower) relative neuromuscular activation, and evidence of incomplete muscle activation despite of a maximum voluntary effort during ECC contractions *A*: variation in torque exerted by knee extensor muscles on an isokinetic device during a maximum concentric contraction (dashed line), eccentric contraction (solid line), and an eccentric contraction with superimposed supramaximal electric shocks (dotted line). *B*: although maximum torque is greater during an eccentric contraction, amplitude of EMG (muscle activation) was greater during concentric contraction and increased with velocity. (Enoka, 1996)

In the previous studies, the most appropriate loadings to maximise eccentric exercising stimulus has not been extensively covered. Most of the studies that are suggesting eccentric training to provide greater strength gains and improvements in neuromuscular functioning are processed in a manner where maximal or sub-maximal concentric loadings are paired with nearly maximal or significantly sub-maximal eccentric loading. In other words, CON and also ECC phase of the repetition are performed through with the same absolute load. The more recent studies have used altering resistance to research the effects of eccentric training benefits. Such loading patterns, where ECC phase of the repetition is followed by CON phase with lower resistance, is often called as DAER repetition (Brandenburg and Docherty, 2002; Doan *et al.* 2002; and Godard *et al.* 1998). The benefit of applying altering resistance at different contraction types of the repetition has been shown to provide extra potential for generation of strength. Thus, the recent studies using this technique have still randomly estimated the quantities of loads used for the eccentric phase, as was done in the studies of Doan *et al.* (2002), Hortobagyi *et al.* (2001), Godard *et al.* (1998) and Brandenburg and Docherty (2002). Doan *et al.* (2002) used 105%, the study of Amiridis (1997) used 110%; Johnson *et al.* (1976), Godard *et al.* (1998) used 40% and Hortobagyi *et al.* (2001) 40-50% greater resistance during ECC phase compared to that of CON phase. Brandenburg and Docherty (2002); and Kraemer *et al.* (2006) used 120% of CON 1 RM as ECC load.

Kraemer *et al.* (2006) found similar GH and La responses at 1RM CON exercising as was found in the condition of ECC contractions with 120% of 1RM. The 120% of 1RM loading condition was suggested to be therefore as intensive as 1RM CON loading. Despite the previous finding, neither the study of Kraemer *et al.* (2006) nor any other study have found optimal ECC loadings neither for hypertrophy nor for maximal power or maximum strength in DAER ECC-CON contractions.

Kraemer *et al.* (2006) and Durand *et al.* (2003) found GH to best indicate the degree of contraction intensity. There was also found that T and FT are not necessarily effective indicators of contraction intensity. Therefore, regarding to Kraemer *et al.* (2006) it is more advisable to use GH together with La than T and FT to detect rapid changes in their concentrations, and also, to provide suggestions of hypertrophy improvements.

The studies of Gravel *et al.* (1987), Tesch *et al.* (1990), and Seger and Thorstensson (2005) have reported that the muscle EMG activation is not as complete during maximal ECC compared with maximal CON contractions. However, it is suggested that ECC contractions provide greater contraction type (Hortobagyi *et al.*, 1997; Seger and Thorstensson, 2005) and speed specific (Seger and Thorstensson, 2005) adaptations to ECC activation compared to CON contractions enhancing CON activation. Hortobagyi et al. (1997) also expected greater EMG activation to reflect a greater mechanical stimulus to muscle fibres for hypertrophy. This encouraged the current study to monitor the degree of activation during ECC contractions at different ECC-CON loading conditions.

Beside maximum strength and 'hypertrophical' strength the total strength is constituted also of power output. Power is often used unit to determine the capacity to do explosive muscle action (Izquierdo *et al.* 1999; Baker *et al.,* 2001; and Cronin *et al.,* 2002). Similarly to power, RFD is defined as the rate of rise in contractile force at the onset of contraction (Aagaard *et al.*, 2001).

The purpose of this study was to find the most efficient ECC-CON loading strategy for muscle hypertrophy by employing various DAER resistances in bench-pressing. Various DAER resistances (CON: 70%; ECC: 80%, 90% and 100% of 1RM) were employed to detect the changes in force responses, neuromuscular activation and in blood serum markers of La and GH. Acute responses of DAER exercising have not been previously studied extensively. This expanded the purpose of the study not only to research the previously found responses of ECC and DAER exercising, but also to monitor the neuromuscular, hormonal and blood serum markers objectively. Optimal eccentric load in eccentric-concentric loading contractions will expectedly help the maximum potential of ECC stimulus to be employed into ECC-CON training.

2 THE FINDINGS IN ECCENTRIC EXERCISING STUDIES

In numerous studies such as in Farthing and Chilibeck (2003), Hortobagyi et al. (1997), Häkkinen and Komi (1981) and Doan *et al.* (2002) the application of ECC stimulus to the muscles have enhanced strength. Also, regarding to Colliander and Tesch (1990) ECC training is shown to produce greater muscle hypertrophy than concentric training. Hence, strength increases and hypertrophy, as themselves, can be used as markers to indicate the muscles to be exposed to ECC stimulus. This can be done by comparing the force production (MVC) at different phases of a repetition and muscle CSA changes between different training groups as an example (Farthing and Chilibeck, 2003). Also, rate of power production changes can be used as a marker reflecting the intensity of ECC stimulus.

EMG is often used to study the extent of ECC stimulus (Agaard *et al.,* 2000). Alterations in neuromuscular activity between ECC and CON contractions and relatively greater increase in ECC neuromuscular activation are common subsequent adaptations following ECC exercise. In some cases a reduction in neuromuscular inhibition is observed.

In studies researching ECC stimulus, effects of neuromuscular activation measurements are often used and paired with ECC contraction related damage measures. Dierking *et al.* (2000), Chen (2003) and Folland *et al.* (2001) presented muscle damage markers to measure muscle soreness by CIR scale (or PRE), CK and in addition to the previous, Chen (2003) used ROM to measure ECC damage. Saxton *et al.* (1995) suggested paired relationship between the CK, impaired ROM and reduced maximum strength after application of ECC exercising. Saxton *et al.* (1995) proposed tremor amplitude and frequency to also reflect the ECC exercise caused damage in some extent. Tremor amplitude was found to increase until 48h after the exercise.

Malm *et al.* (2004) presented findings that eccentric physical exercise (downhill running) did not produce inflammation 48h post exercise, despite increased CK and experienced DOMS. However, inflammation is often related to increases in CK and DOMS in previous literature. The unrelated inflammation finding is supported by Dierking *et al.* (2000). They found diagnostic ultrasound scanning not to be sensitive enough a method to detect any significant differences in muscle intramuscular swelling at pre and post eccentric exercise conditions. Funato *et al.* (2000) could not either find any significant differences in B-mode ultrasound based CSA measurements in two different groups of weight-lifters although other of the two groups had significantly higher base maximum strength. Despite the fact that ultrasound has been used in many previous studies to analyse the intensity of an ECC stimulus the current study did not use an ultrasonography method to determine muscle inflammation as it has not been shown to be sensitive enough a method.

To determine the actual muscle CSA increases longitudinal studies such as Häkkinen and Pakarinen (1994) are needed. However, acute studies are capable to provide estimations of an optimal loading for muscle hypertrophy, for instance, based on anabolic hormone concentration measurements such as in a study of Kraemer *et al.* (2006). To allow a research for determination of an optimal loading for hypertrophy this is most often done in studies measuring pre- and post strength training period triggered effects on CSA, anabolic hormones, and muscle strength (Farthing and Chilibeck, 2003, and Moss *et al.,* 1997). The study of Moss *et al.* (1997) researched the effect of different loads on dynamic strength, CSA, load-power and load-velocity relationships in 9 weeks training treatment study. However, it was found that the increase in 1RM did not occur in parallel with the increase in CSA of the elbow flexors. Therefore, muscle strength cannot be kept as a valid single indicator of hypertrophy.

A more extraordinarily, there has been observed increases in the number of sarcomeres in series post ECC exercising. In longitudinal training treatments ECC stimulus is suggested to result in an additional number of sarcomeres in series. For example Lynn *et al.* (1998) and Butterfield *et al.* (2005) used a sarcomere counting method to evaluate the training treatment differences between incline and decline running groups of rats. Alternative method to determine the muscle length change is to use a length-tension relationship comparison. (Figure 2). The length-tension change is often determined in isometric force measurements at different angles that provide the most accurate determination of force at particular muscle lengths such as in a study of Hulmi (2003). Therefore angle based estimations on muscle length changes can be observed in a synchronised joint angle (i.e. goniometer) and force recording analysis.

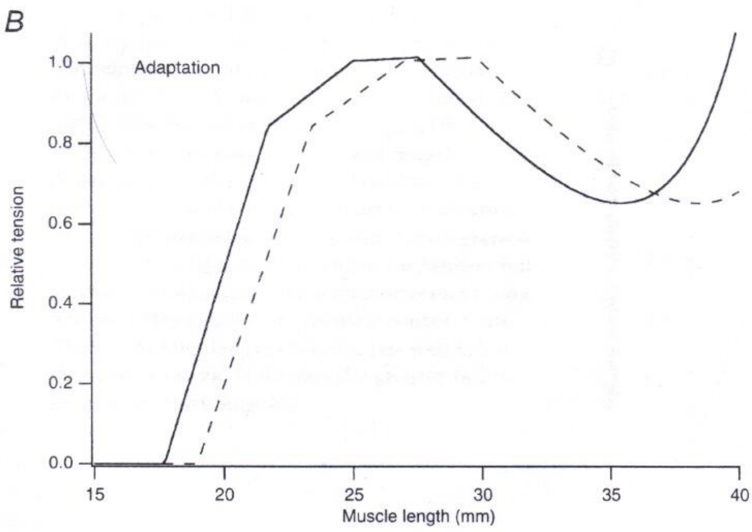

FIGURE 2. Muscle length- tension relationship where, control (continuous curve) and the curve after the number of sarcomeres in series have been increased by 10% (dashed curve) (Edited by Proske and Morgan, 2001; from the original of Gordon *et al.*, 1966). The increase of sarcomeres is presumed based on the switch in optimal length for maximum tension exertion.

3 NEUROMUSCULAR ACTIVITY

3.1. Neuromuscular activity and inhibition

Voluntary muscle force is not only determined by muscle CSA (Schantz *et al.* 1983) and architecture (Aagaard *et al.* 2001), but also by neural drive to muscles (Karlsson and Gerdle, 2001). In the study of Aagaard *et al.* (2000) motoneuron activation is reported to be lower during maximal voluntary eccentric and slow concentric contractions compared to fast concentric contractions. After heavy resistance training this existing inhibition is often seen to be reduced (Aagaard *et al.*, 2000).

According to Dudley *et al.* (1990) and Westing *et al.* (1991) a presence of substantial neuromuscular inhibition occurs during maximal eccentric contraction. Komi (2000) reported that proprioseptic inhibition increases after fatiguing SSC exercise, which is discussed in following sections. Neuromuscular inhibition is seen with superimposed electrical stimulation (Figure 1) on to maximal eccentric contraction (Dudley *et al.*, 1990; and Westing *et al.*, 1991). In other words, there will be an increase in EMG signal during the maximum ECC contraction, which indicates the additional force burst that is the amount of inhibition. The neuromuscular inhibition occurrence during ECC contractions is suggested to be further supported by the existence of lower EMG activity during ECC contractions compared to CON or ISOM contractions (Agaard *et al.,* 2000; Tesch *et al.*, 1990; and Komi *et al.,* 2000).

The neuromuscular inhibition, reduction in neural activation, could be caused by inhibitory feedback via sensory group I and II afferents. The sensory Ib afferents from Golgi tendon organs and Ia and II afferents from muscle spindles converge onto the entire motorneuron pool. This convergence is not only from the muscle itself (homonymous afferent pathway) but also from the antagonist (heteronymous pathway). After resistance training the homonymous motorneuron inhibition is reduced probably due to presynaptic gating from supraspinal centres and this Ib afferent inhibiton reduction will increase the force of contraction. (Jami, 1992).

3.2. Antagonist co-activation

Enoka (1994) suggested that co-activation refers to concurrent activity in the muscles comprising an agonist-antagonist set. Co-activation has a mechanical effect that makes the joint stiffer. Hence, it is important in acquiring of a stable basis for a movement. Co-activation seems to be useful feature when an individual learns novel tasks or in performances that requires high degree of accuracy. (Enoka, 1994). Antagonist co-activation is often reported in relative percent torque or relative percent linear force ratios of agonist activation. The percentage contribution of antagonist moment was reported in a study of Kellis (2003) to range from 7.1 to 60.4% throughout the range of motion of knee extension. Kellis and Baltzopoulos (1999) reported maximum antagonist force of 2.55 times BW and 1.16 times BW during concentric and eccentric conditions respectively.
In the study of Kellis (2003) was reported there to be available only limited amount of

studies to quantify the antagonist moments. However, antagonist hamstring muscle moment was reported to be around 10-15% of the total moment recorded by isokinetic dynamometer Kellis (2003). Regarding to Seger and Thorstensson (2005) antagonist activity is reported controversially to respond to ECC stimulus. No differences were recorded between the groups but there was reported a trend towards smaller relative hamstring (antagonist) activation for CON training group after ECC testing (antagonist co-activation ranged from 19 to 38%) (Seger and Thorstensson, 2005). A reduction in antagonist co-activation would be observed in EMG signal (figure 3) as lesser activity. In the figure 3 antagonist and agonist EMG activity is presented during a bench press performance.

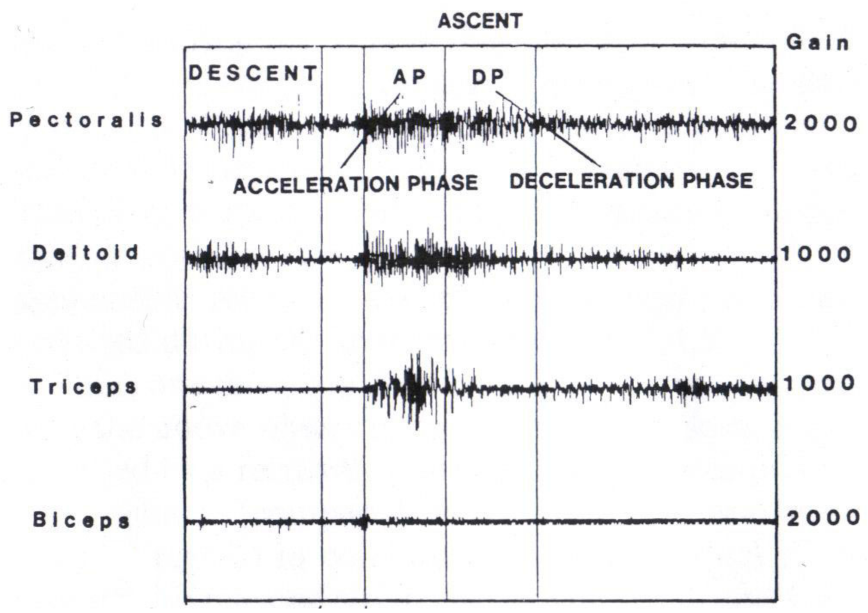

FIGURE 3. EMG data from a bench press performance with 81% of 1RM load (Elliott *et al.*, 1989). Agonist muscle during the bench-press performance are pectoralis, deltoid and triceps brachii, and antagonist muscles is biceps brachii.

3.3. The role of fatigue in antagonist co-activation

The contribution of antagonist muscles in total force production may change also as a result of fatigue. The force production contribution of each muscle around the joint may change during a performance with increasing fatigue process at each muscle. (Kellis, 2003).

Fatigue may lead to a change in balance of forces between agonist and antagonist muscles. In such a case of declined force output in agonist comparatively to antagonist force this may lead to a decline in mechanical output (Bentley *et al.*, 2000). According to Komi (2000) a reduction in stretch-reflex component after fatiguing SSC contraction also contributes to antagonist functioning. This is because of a muscle spindle disfacilitation due to fatigue progression, and in addition, of activation of III and IV afferent nerve endings. This reduces stretch reflex sensitivity and muscle stiffness that will impair the force potentiation mechanism. (Komi, 2000).

3.4. Neuromuscular functioning after exposal to ECC or SSC contractions

In the study of Komi (2000) the SSC action of a muscle was discussed to be such muscle action where the muscles were periodically subjected to impact or stretch forces. In the lengthening phase the muscle is acting eccentrically, which is followed by a CON action. The essential definition of ECC action indicates that the muscles must be active during stretch. SSC has a recognized purpose to enhance the performance during the final phase of CON action. (Komi, 2000).

Exposure to ECC stimulus is reported to provide greater strength development and therefore greater force output (Hortobagyi *et al.*, 1997; Seger and Thorstensson, 2005). Also, there are reported greater speed specific adaptations (Seger and Thorstensson, 2005) after exposing to ECC contractions. The exposure to ECC stimulus is observed to lead to greater ECC EMG activity and ECC force production compared to smaller increases seen in CON activation improving CON force and CON EMG activity (Hortobagyi *et al.*, 1997). Therefore ECC contractions are considered to provide greater contraction type specific development. For instance, Hortobagyi *et al.* (1997) reported seven times greater ECC neuromuscular activation after ECC contractions (pre/post 86%, $P>0.05$) than CON contractions enhanced CON activation. Similarly, Hortobagyi *et al.* (1997) reported contraction type specific but also greater ISOM strength adaptations after ECC exercises (22% vs. 39%).

In the study of Hortobagyi *et al.* (2001) the increases in isokinetic and isometric forces were proportional to EMG activity increases. In figure 4, is an illustration of the absolute changes in isokinetic and isometric forces in EO and ST training groups and absolute changes in vastus lateralis root-mean-squared EMG activity during isokinetic eccentric and isometric contractions. The relationship between the forces and EMG was seen as vastus lateralis and medialis EMG activity were similarly increasing comparing to isokinetic and isometric force values. VL EMG activity during the eccentric test increased by 347µV, which was significantly more ($P < 0.05$) than the increase during the isometric (194µV), or during the concentric test (117µV) (Hortobagyi *et al.*, 2001).

Figure 4 offers also an illustration of the EO to improve significantly more ECC 3RM force than ST, 125N vs. 49N respectively ($P < 0.05$). CON 3RM force improved to the same extent in both of the groups, (EO = 65N and ST = 58N).

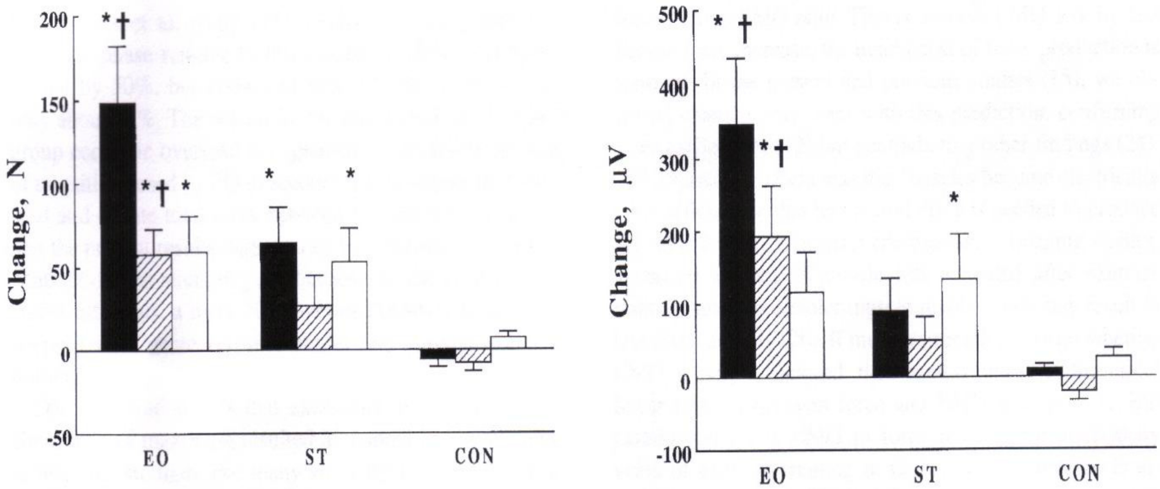

FIGURE 4. Left: Absolute changes in isokinetic eccentric (filled bars) isometric (hatched bars), and isokinetic concentric forces (open bars), in EO, ST, and control groups. The largest gain occurred in eccentric force in EO (149N) that was 2.8-fold more than the change in concentric force in ST. Right: Absolute changes in vastus lateralis root-mean-squared EMG activity during isokinetic eccentric (filled bars), isometric (hatched bars) contractions. Left and right: *significant post training change and † significantly greater changes than the changes in the same measures in ST ($P < 0.05$). (Hortobagyi *et al.,* 2001)

As mentioned in the introduction, eccentric exercising is associated with a greater mechanical efficiency despite of lower neuromuscular activation. This is discussed to be due to innervation of greater size muscle fibres as illustrated in figure 5 (Enoka, 1994). The previous suggestion was supported by the study of Linnamo *et al.* (2003) where low force level mean spike amplitude was higher in ECC compared to CON actions, which might indicate of a selective activation in fast motor units. However, contradicting findings have been presented to the previous suggestion (Seger and Thorstensson, 2005; Komi *et al.*, 2000). In the studies of Seger and Thorstensson (2005) and Komi *et al.* (2000) were reported no occurrence of neural mechanism related adaptations in selection of greater muscle fibres post ECC exercises compared to post CON exercises.

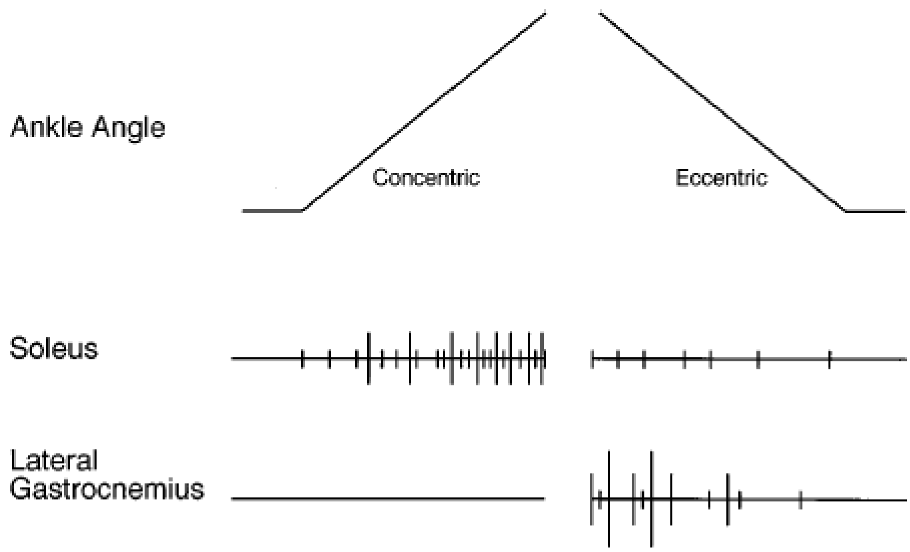

FIGURE 5. Motor unit activity (idealized action potentials) in soleus and lateral gastrocnemius muscles of a human volunteer as ankle angle increased (concentric contraction) and decreased (eccentric contraction) to raise and lower a load. Eccentric contractions involved activation of high-threshold motor units with large amplitude action potentials. (Enoka, 1996)

Despite of the fact that ECC contractions are reported to result with greater force generation capacity and greater contraction type specific outcomes, ECC exercising is not often reported to provide superior capacity in removing or reducing neuromuscular inhibition compared to CON exercising such as found in the study of Hortobagyi *et al.* (1997). Hence, neuromuscular inhibition removal is expectedly helped at the same degree with CON and ECC contractions. Force of contraction can be seen to be reinforced by removal of neuromuscular inhibition. The neuromuscular inhibition changes associated to DAER exercises is not studied in our knowledge.

3.5. Cross-learning (cross-education) and bilateral deficit

Cross education and bilateral deficit are manifestations of neural integration of interlimb coordination (Howard and Enoka, 1991). Cross-education was first described by Scripture *et al.* (1894) to be a chronic effect that takes the form of performance enhancement in an inactive limb musculature following exercise training of a remote limb. Regarding to Kuruganti and Seaman (2006) the bilateral limb deficit is describing the difference in maximal or near maximal force generating capacity of muscles when they are contracted alone or simultaneously with the contralateral muscles. Bilateral deficit occurs when the summed unilateral force is greater than the bilateral force.

Various studies have reported markedly greater improvements in cross learning after ECC only exercises than after CON only exercises. The studies of Hortobagyi *et al.* (1997) and Seger *et al.* (1998) suggested significantly greater ($P < 0.05$) strength in eccentrically trained contralateral leg compared to concentrically trained leg. Figure 6 presents the differences in ECC and CON training to cross education (Hortobagyi *et al.*, 1997).

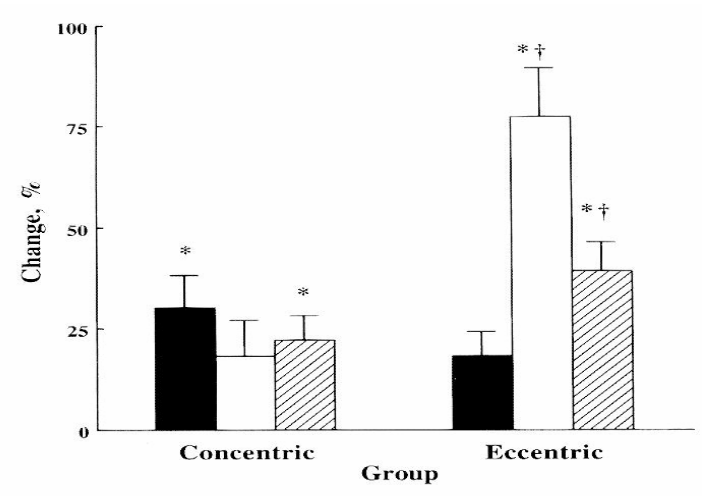

FIGURE 6. Percent pre- to post-training changes in contralateral quadriceps muscle strength as assessed with concentric (filled column), eccentric (open column), and isometric (hatched column) test contractions, following ipsilateral concentric or eccentric training. Vertical bars denote ± SD* Significant change and significantly more change than the concentric group (Hortobagyi *et al.*, 1997). This suggests the ECC contralateral strength (cross learning) to be remarkably greater after ECC exercising than ECC, ISOM or CON strength after CON exercising.

4 ENDOCRINE PARAMETERS AND LACTATE

The endocrine parameters of GH, T and FT, and also lactate, are often used metabolic markers for assessment of intensity of the contractions as in the studies of Durand *et al.* (2003) and Kraemer *et al.* (2006). Regarding Gotshalk *et al.* (1997), Kraemer and Häkkinen (2002) and Kramer *et al.* (1990) increases in serum GH appear to be the greatest during hypertrophic type of exercises when using reasonably high numbers of repetitions and sets. In the figure 7 is an illustration of GH measurement in a study of Linnamo *et al.* (2005) where 3 different loading regime exercises were used to monitor hormonal responses of GH and T at different time intervals. Kraemer *et al.* (1991) and Viru (1992) suggest the serum T level to increase also during strength exercise if the exercise stimulus is sufficient.

A

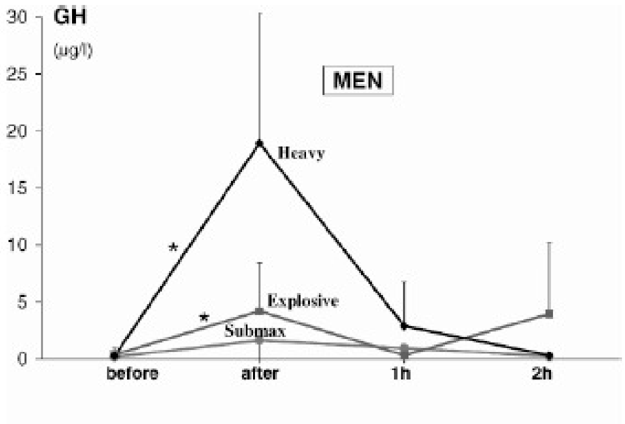

FIGURE 7. A: Mean (6 SD) values for serum growth hormone (GH) concentrations before and after the exercises in (a) men and (b) women (*, p<0.05).

B

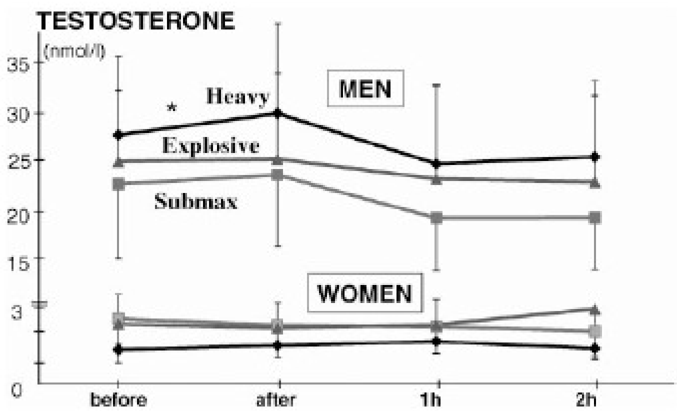

FIGURE 7. B: Mean (6 SD) values for serum testosterone concentrations before and after the exercises (*, p<0.05). (Linnamo *et al.* 2005).

Kraemer *et al.* (2001) and Overend *et al.* (2000) stated that CON contraction results with higher metabolic responses than ECC contractions, once performing with the same absolute resistance. Kraemer *et al.* (2006) suggested that 120% of CON 1RM is supposedly at the proximity of ECC 1RM intensity. In the study of Kraemer *et al.* (2006) the relationship between CON and ECC exercises was studied with GH, La and FT measurements (Figure 8 and 9). Kraemer *et al.* (2006) found La and GH to be reliable single indicators of intensity whereas free testosterone concentration was not sensitive enough to respond to rapid changes in intensity (figure 8 and 9). Hence, based on the previous finding the ECC resistance of 1.2 x CON 1RM is expectedly as intensive as 1 x CON 1RM. According to the previously presented findings of Kraemer *et al.* (2006) and Durand *et al.* (2003) combined utilisation of La and GH concentration analysis allow reasonably consistent determinations on intensity irrespective of the type of contraction (CON, ECC) in dynamic conditions.

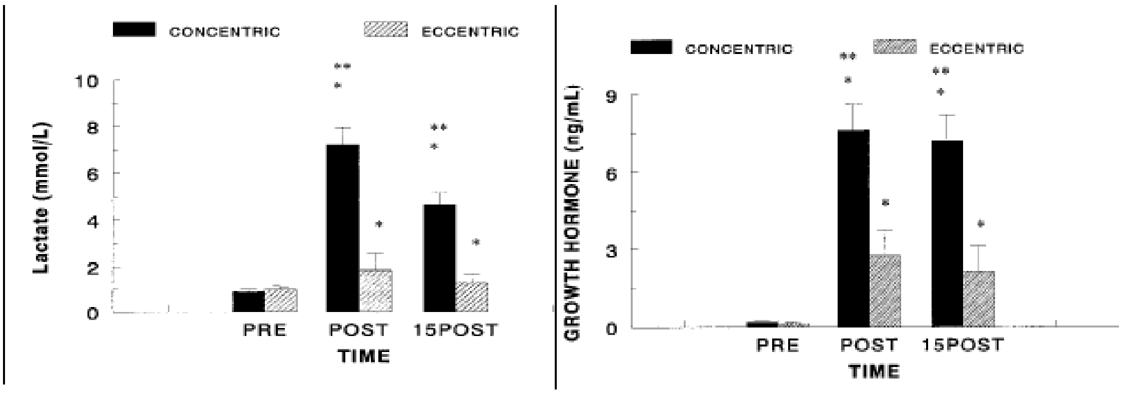

FIGURE 8. Lactate (left) and GH (right) concentrations (mean SE) during the experimental trials for CON (solid bar) and the ECC trial (hatched bar). ** Significantly different between the CON and ECC trials ($P < 0.01$). * Significantly different from prevalue ($P < 0.01$) (Durand *et al.*, 2003).

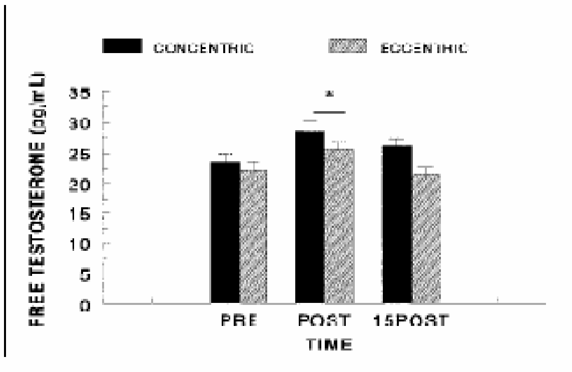

FIGURE 9. Free testosterone concentrations (mean SE) during the experimental trials for CON (solid bar) and the ECC trial (hatched bar). * Significantly different from prevalue ($P < 0.01$). (Durand *et al.*, 2003)

5 STRENGTH, POWER-VELOCITY, FORCE-VELOCITY AND RFD

Generally, strength is regarded as the capacity to do work. The explosive strength can be best measured by determining the rate of doing work with a certain velocity (VanPraagh, 1998). Power is defined by velocity and force and is used as a measure of explosive strength (Izquierdo *et al.,* 1999; Moss *et al.*, 1997; Baker *et al.,* 2001a and Cronin *et al.,* 2002). The force-velocity relationship is related to the maximum power output as illustrated in figure 8. Regarding to Enoka (1994) the highest power output is attained at optimal velocity that is determined to be approximately 1/3 of the maximum force (figure 10). Confusingly, VanPraagh (1998) determines maximal power to be attained at an optimal velocity that is in isolated animal experiments about one-third of the maximum velocity. It has to be noted that the figure 8 does not provide information of force-velocity relationship during ECC contraction as force is reported to be unaffected by changes in the velocity of lengthening (Figure 1), at least, beyond a certain limit (Enoka, 1996). However, Linnamo *et al.* (2006) suggested the relative ECC force potentiation to be velocity dependent force generation being the smallest at the lowest stretching speed.

However, as a force is a product of mass and acceleration power output is found to be the highest at optimal velocity and load (Moss *et al.* 1997). According to Enoka (1994) the force-velocity relationship represents the dynamic capability of muscle that includes the effect of the rate of change in the amount of thick and thin filament overlap on muscle force. The highest force during SSC is detected in movements with fast contraction velocity, such as in jumping and hopping. From this can be interpreted that series elastic component is storing energy most effectively during fast ECC velocity of a movement for later usage in CON phase (Enoka, 1994).

However, the ECC phase of a contraction is reported to be largely unaffected by changes in the velocity of lengthening (Figure 1 at introdution), at least beyond an initial limit, and CON contraction to follow force-velocity relationship (Enoka, 1996). Moss *et al.* (1997)

discussed the greatest force output to take place at or at a proximity of training velocity. This suggests of the speed specific adaptations capacity of a muscle. Moss *et al.* (1997) also stated that the velocity relation to performance has been only extensively researched with isokinetic studies such as Andersen *et al.* (2005) and Aagaard *et al.* (2000). In these studies are presented concurrent findings with figure 1 suggested outcomes in ECC and CON force-velocity relationships. Force-velocity relationship is illustrated in the figure 1 (section B, page 8).

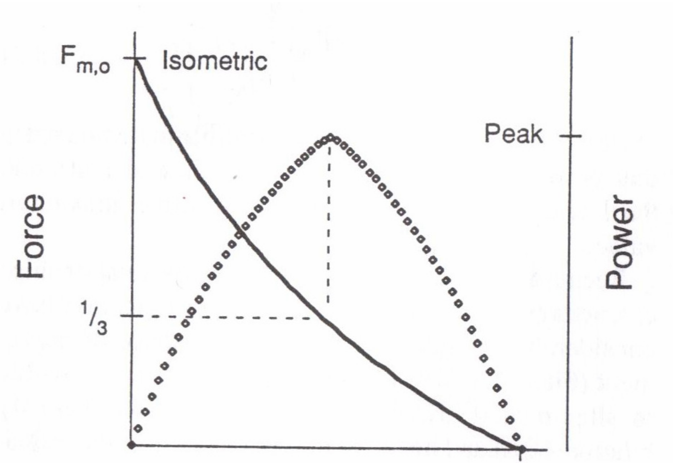

FIGURE 10. Edition of force-velocity relationship (Hill, 1950) representing force-velocity (solid line) at isolated-muscle preparation, horizontal bar is the velocity response. The power curve (right-hand vertical axis) is derived from the product of force and velocity. (Enoka, 1994)

Accorging to Aagaard *et al.* (2001) the maximal rate of rise in muscle force, in other words, RFD determines the force that can be generated in the early phase of muscle contraction. This is supported by Häkkinen *et al.* (1985) as they defined explosive muscle strength to be the rate of rise in muscle force. Aagaard *et al.* (2001) suggested the time interval for RFD determination to be 0 to 200 ms. In intact joint actions RFD is calculated from the slope of the joint moment-time curve, where as in isolated muscle preparations contractile RFD is obtained from the slope of the force-time curve (Aagaard *et al.*, 2001).

5.1 Force, power and RFD in studies with altering resistance approach

Neither RFD nor power responses have been extensively studied in DAER studies. However, force output has been studied in number of DAER resistance training experiments such as in Hortobagyi *et al.* (2001); Doan *et al.* (2002), Brandenburg and Docherty (2002); and in Godard *et al.* (1998).

The study of Hortobagyi *et al.* (2001) compared regular strength training (isoinertial) to DAER training in 7 consecutive days training protocol. In this study eccentric 3RM force increased by 27% or 125N in EO, whereas the same increase was 11% or 49N in the ST group (figure 11). The previous increase observed in EO was significantly greater than the increase in ST. Also, isometric force increases were significantly greater in EO group than in the ST group (58N vs. 27N, P < 0.05. ST exercised in a conventional sequence of concentric followed by eccentric contraction, whereas EO used 40-50% overload during the eccentric phase of the contraction. Control group was also employed to this study but no significant differences were observed in this group.

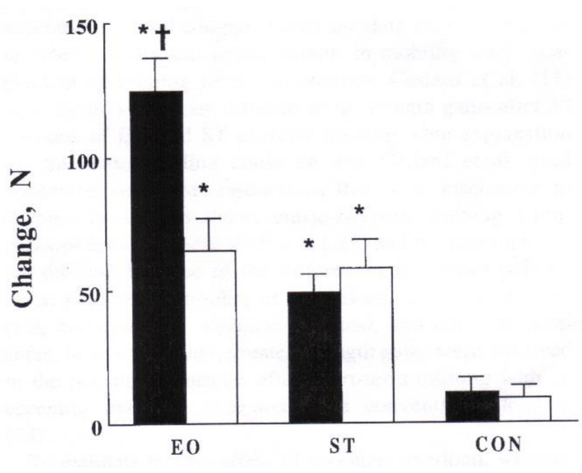

FIGURE 11. Absolute changes (in Newtons) in eccentric (closed bars) and concentric (open bars) 3RM in the EO, ST, and control groups in a 7 consecutive days training protocol. The largest 125N change in eccentric 3RM in EO was about 2.9-fold more than the change in concentric 3RM in ST; *significant pre- to post-training change and † significantly greater changes than any other changes (P < 0.05). (Hortobagyi *et al.* 2001)

In the study of Doan *et al.* (2002) altering resistance between ECC and CON phases of maximum strength repetition was observed to improve bench-press 1RM significantly (P = 0.008) compared to the non-significant increase seen in the control conditions. 1RM increased in all of the subjects by 5 to 15 pounds from control to experiment condition. These results were achieved by applying additional ECC load that was employed by a weight releasers technique to a bench-pressing movement (Figure 18).

In the study of Brandenburg and Docherty (2002) DAER was observed to produce significantly greater increases in elbow extensor 1RM strength than DCER. DCER training significantly increased CON 1RM of the elbow flexors by 11% and extensors by 15%. DAER training similarly increased CON 1RM of the elbow flexors by 9%, but extensors strength was more extensively improved by 24%. The previous values are illustrated in figure the 12 as absolute values. DAER was defined to be a training method to produce higher levels of force generation during eccentric actions. The training consisted of 9 week either DAER or DCER free weight elbow extensor and flexor training. DCER performed 4 sets x 75% of 1RM ECC-CON contractions. Alternatively, DAER group performed 3 sets x (75% CON + 120% of 1RM ECC). Brandenburg and Docherty (2002) suggested 9 weeks DAER training to be more effective than DCER training in developing strength in some exercises.

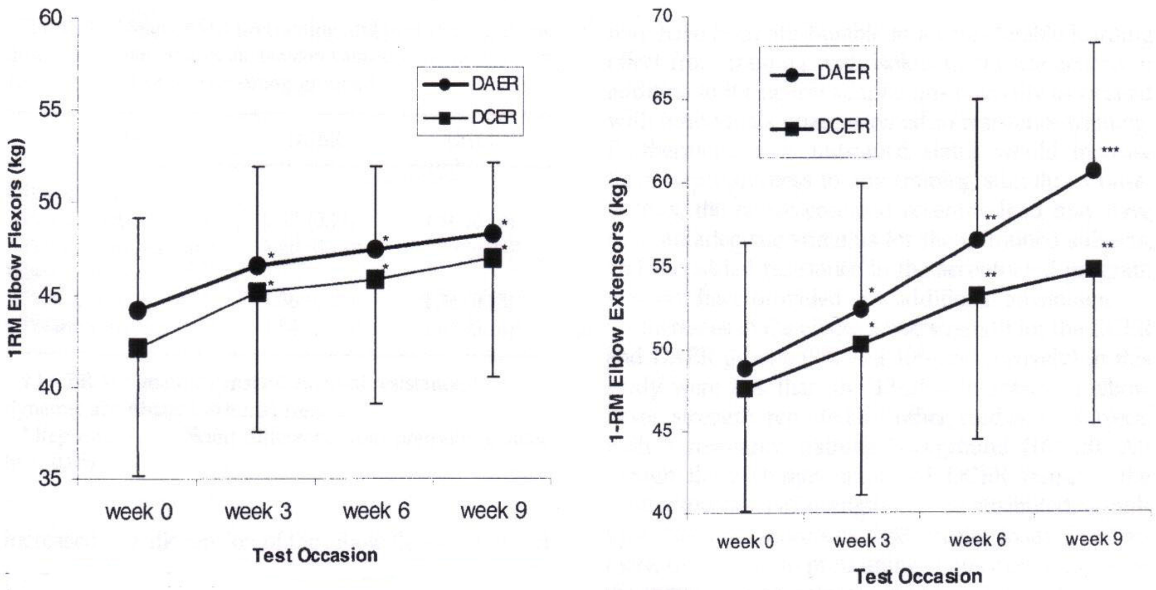

FIGURE 12. Left: Mean values for CON 1RM of the elbow flexors over the duration of the study (* Indicates significant difference from the week 0, P < 0.05). Right: Mean values for CON of the elbow extensors over the duration of the study (* Indicates significant difference from the week 0, ** indicates significant difference from the week 3,*** indicates significant difference from the week 6 and from the DCER group at week 9, P < 0.05). (Brandenburg and Docherty, 2002)

In contrast to the findings of Brandenburg and Docherty (2002), and Doan *et al.* (2002) the results in the study of Godard et al. (1998) suggested DAER training not to provide any further enhancement in maximal CON torque in 10 weeks knee extensor training. Results showed significant increases in both training groups of CON-ECC and CON-ECC with DAER resistance. The latter training group was using DAER of 40% in addition to CON load during ECC phase of contraction. CON-ECC group improved from 85.8 ± 23.3 to 167.4 ± 35.5N and CON-ECC+ from 88.0 ± 20.9 to 170.4 ± 32.4N. There was observed no significant differences between the training groups in strength changes or in changes of muscular CSA.

6 OPTIMAL LOAD FOR MUSCLE HYPERTROPHY

In the chapter 5, strength was defined as the capacity to do work. Work is constituted of power multiplied by time, or alternatively force multiplied by displacement. However, regarding to Van Praagh (1998) and Komi (2003) the length of a muscle highly determines the velocity of a contraction and muscle fibre CSA determines the force of a contraction. Force is constituted of acceleration and mass. Acceleration, for its behalf, is constituted of velocity and time. The previous statements would allow us to discuss the force to be dependent not just on the muscle fibre CSA determinant but also being dependent of velocity of a contraction. This concept is concurrent with the definition of strength provided by Knuttgen and Kraemer (1987): "Because of the number of variables or conditions involved, strength of a muscle or muscle group must be defined as the maximal force generated at a specified or determined velocity". As a summary of the previous concepts the force, power, and muscle hypertrophy development is the greatest with application of appropriate quantities of all the three types of strength exercises (maximum strength, explosive strength and 'hypertrophical' strength). The optimal loading strategies for two constituents of strength are outlined in this chapter.

6.1. The optimal load for increases in muscle CSA

Regarding to numerous studies, such as Fleck and Kraemer (2004), Kraemer and Ratamess (2004); and Kraemer *et al.* (2002), the optimal load for muscle hypertrophy is found within the loads corresponding 6-12RM, or more accurately, within 8-10RM (Mazzetti *et al.* 2000). Regarding to Linnamo *et al.* (2005) the loading is advised to be near the maximum (e.g. 70–80% 1RM), but each set should be performed until the 8–12 repetition maximum (8–12RM). In contrary, in the study of Moss *et al.* (1997) a training group with resistance of 35% of 1RM had minor increase in CSA of 2.8% ($P < 0.05$). Despite of the small increase in CSA there were high correlations between 1RM and CSA ($r = 0.88$, $P < 0.0001$, $n = 30$) and between maximal power and CSA ($r = 0.81$, $P < 0.0001$, $n = 30$). This study suggests smaller RM based loads to be sufficient for muscle hypertrophy in some conditions. Hoffman *et al.* (2003) found testosterone and GH levels to be greater after a light-intensity, high-volume (15 repetitions with 60% of 1-RM) training compared to high-intensity, low-volume (4 repetitions with 90% of 1-RM) exercise protocol (figure 13). Also muscle oxygen recovery kinetics was found to be influenced by differences in the intensity and volume of exercise, and delayed reoxygenation was found to affect the GH response to exercise.

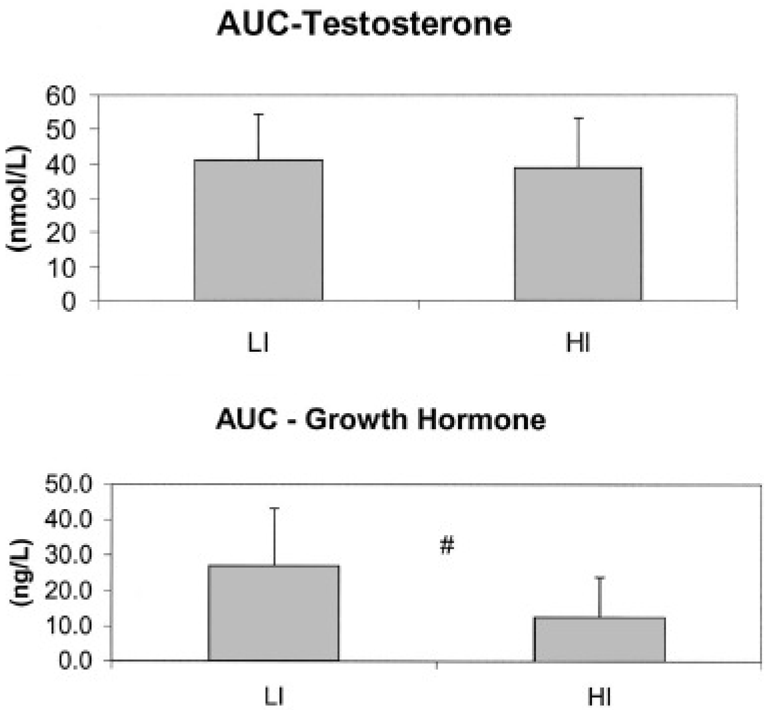

FIGURE 13. TOP: Comparison of serum testosterone concentrations (mean±SD) for various time points and resistance exercise intensities. BOTTOM: Area under the curve (AUC) testosterone responses (mean±SD). # Significantly different from Pre; LI = 60% 1RM; HI = 90% 1RM. (Hoffman *et al.,* 2003)

As discussed in the introduction the optimal loads for muscle hypertrophy in DAER loading conditions has not been previously studied extensively. However, the findings of La and GH levels in the studies of Kraemer *et al.* (2006) and Durand *et al.* (2003) can be seen to provide reasonable accurate predictions towards the loading quantities in research of optimal ECC load for hypertrophy. Kraemer *et al.* (2006) stated the ECC training load 120% to be respective with CON 1-RM and therefore produce similar intensity response if observing the hormonal response to independent ECC and CON exercises in 4 sets of 10 repetition sets. However, through the observed pilot data and regarding previous findings Kraemer *et al.* (2006) found that 65% of 20% > CON 1-RM for ECC contractions and 65% of CON 1-RM for CON contractions best equalized perceptions of stress and ensured completion of protocol for the respective muscle actions. The findings of Durand *et al.* (2003) concurred with the statements of Kraemer *et al.* (2006). CON exercise was found to increase GH concentrations to a much greater extent than ECC exercise at the same absolute load, and also, there was suggested that greater GH responses were related to intensity rather than to mode of contraction. However, these studies were conducted with separate ECC and CON contractions and therefore the findings cannot be kept reliable once estimating optimal resistances for DAER loading conditions.

According to our knowledge the study of Brandenburg & Docherty (2002) is a novel experiment that has compared muscle hypertrophy changes in DAER exercising to isoinertial exercising. Despite of the significant increases in strength development with ECC load of 45% greater compared to CON, Brandenburg & Docherty (2002) concluded neither of the training protocols to be effective in eliciting muscle hypertrophy. However, this hypertrophy (CSA) measurement suffers of severe limitation as Brandenburg & Docherty (2002) reported of tester's unawareness regarding the organization of MRI images. The tester possible mixed the pre and post MRI images during the CSA measurements.

6.2 The optimal load for maximum strength and contribution of device settings

The maximum strength level is often measured by 1RM tests. Moss et al. (1997) suggested that that heavy resistance training increases 1RM. Some authors suggest that maximal isometric strength is highly corresponding maximum dynamic strength of 1RM (Berger 1962; Thorstensson et al. 1976; McDonagh and Davies 1984; Häkkinen et al. 1985). Maximum strength output is the best improved with a load of 1-3RM (Kraemer and Ratamess, 2004; and Kraemer *et al.,* 2002), correspondingly the load can be selected by applying a resistance of 90-100% of 1RM.

As discussed earlier in the introduction the optimal loads for maximum strength in DAER loading conditions has not been previously studied in detail. The DAER loading suggestions for peaking maximum strength are limited to a study of Doan *et al.* (2002) where positive development was associated with the experimental DAER loading condition compared to the trace change in force output in the control condion. Concurrently, with the results of Doan *et al.* (2002) in the study of Brandenburg and Docherty (2002) was reported significantly greater improvement in elbow extensor maximum strength after DAER resistance training compared to the increase seen after isoinertial training. Brandenburg and Docherty (2002) used 120% 1 RM resistance as eccentric load during the DAER training meaning 45% greater load during ECC phase compared to CON phase (CON = 75% 1RM). In contrary to the loads applied in the latter studies, in the study of Godard *et al.* (1998) was used DAER ECC resistance that was 40% greater than CON resistance. Godard *et al.* (1998) found no significant differences between isoinertial and DAER training groups in maximum torque development from pre to post measurement. This could be of an indication to provide suggestions towards the optimal DAER resistances to stimulate maximum strength. However, the fact that Godard *et al.* (1998) used isokinetic dynamometer, whereas Doan *et al.* (2002) and Brandenburg & Docherty (2002) used free weight loading strategy during the training has to be noted before any conclusion to the quantities of DAER resistances can be made. In other words, the contrast finding observed by Godard *et al.* (1998) could be related to the different training device used and also to the different DAER resistance used compared to the studies of Brandenburg & Docherty and Doan *et al.* (2002).

Despite of the previous finding of Godard *et al.* (1998) in the study of Hortobagyi *et al.* (2001) was used isokinetic dynamometer as training device leading to twofold greater increase in force output after DAER training compared to the standard training group that used isoinertial resistance (seen in figure 14). Hortobagyi *et al.* (2001) used ECC resistance of 40-50% greater comparing to the load used for the CON phase.

7. KINEMATICS AND KINETICS IN BENCH-PRESS MOVEMENT

7.1. The bench pressing regions and the effect of 'sticking region'

Lander et al. (1985) defined a bench press performance with maximum of 100% 1RM resistance to be divided into 4 regions of CON activities: acceleration, sticking, maximum strength and deceleration region (figure 16). A "sticking region" is defined as the portion of free-weight activity when the exerted force application is less than the weight of the bar. In the study of Lander *et al.* (1985), there was observed no significant difference ($P<0.05$) between loading conditions of 90% of 1RM (26.02%) and 75% of 1RM (26.94%) mean relative time values for these 4 regions. In other words, the sticking region remained as extensive in both of the loading conditions. (Lander et al., 1985). In successful bench press performance the magnitude of force attained at the acceleration period has to be such that the sticking region is passed through by the initial burst of force. Once the sticking region is passed the maximum force is reached and followed by deceleration phase once the load overcomes the exerted force and reduces the vertical velocity of a bar. (Elliott et al., 1989). However, the time frame of the sticking region can be manipulated by successive resistance exercises. This is possible based on a theory of Shadwick (1990) who stated that the degree of ground reaction forces applied on tendons to have influence on tendon growth and structure. Regarding to this statement the occurrence and the degree of various "phases" during a forceful repetition are possible to be manipulated.

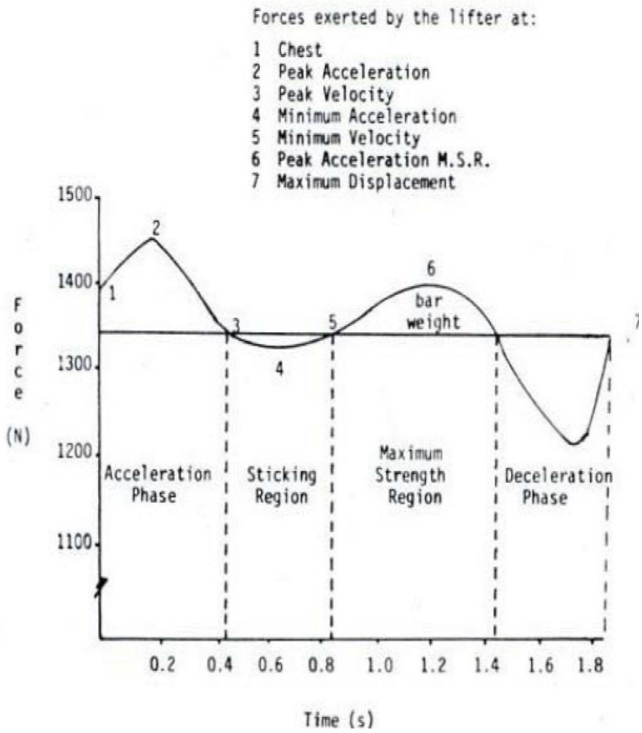

FIGURE 16. Right: Force-time curve exerted by a representative subject (PS) for the 100% load. Lander *et al.* (1985) suggested 4 regions of the lift (Elliott *et al.*, 1989).

7.2. Bench press movement

Competitive performance in bench pressing is defined by International Power-lifting Federation as follows: Initially taking the bar with the upper limbs extended while lying on a bench. The bar is from then on lowered to the chest and after a momentary pause, of average duration 18ms (Elliott *et al.*, 1989), where the bar is motionless. The bar is then symmetrically pushed up until the upper limbs are fully extended. (International Power-lifting Federation, 1984). The phase demanding the greatest force generation during the bar ascend is called as the sticking region. The greatest force output phase in bench-press exercise is outlined in figure 15.

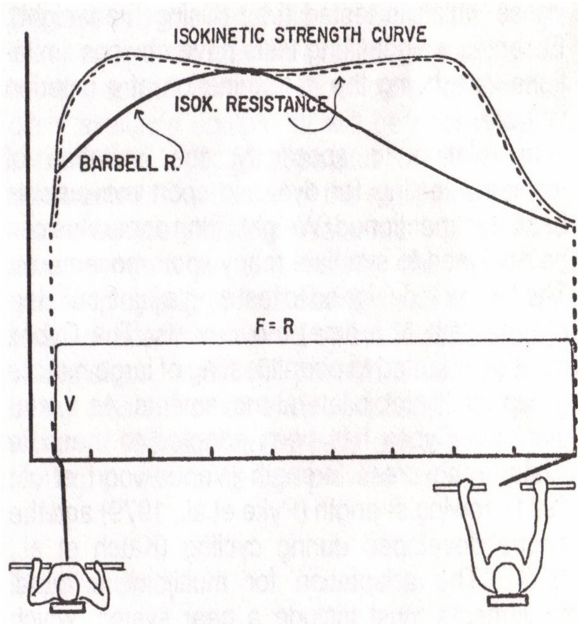

FIGURE 15. Left: Comparison between an isoinertial barbell movement and an isokinetic movement during bench pressing. Top solid line shows the force curve obtained when a maximal contraction was performed at a slow velocity on the isokinetic device. Obviously the resistance offered by the isokinetic device (dotted line) matches the force curve. In contrast the isoinertial resistance of barbell does not match the force curve. The sticking region can be found between the 3rd and 4th tick mark where the load curve approaches the strength curve. Bottom line indicates the solid velocity (v) and force (F) equalled the resistance (R) in isokinetic performance. (McDougall *et al.* 1991)

7.3. EMG activity during different regions of a bench press performance

Figure 17 illustrates the EMG activation during bench pressing performance in a successful 81% of 1RM lift and in unsuccessful 104% of 1RM lift. As illustrated and reported by Elliott et al. (1989), the ECC phase of a bench press performance the agonist muscles of pectoralis major, triceps brachii and anterior deltoid are observed to contract moderately, and occasionally, at maximal activity level throughout the bar descent. Biceps brachii is seen to provide a burst of moderate activity especially towards the end of the descent phase. This takes place especially when the load is increased. Once applying International Powerlifting Federation rules to the performance the pause (av. 18ms) period at the end of the ECC phase is associated with reduced EMG activity. (Elliott *et al.*, 1989). The reduction in EMG activity is explained by the dissipation of elastic energy during the pause period (Enoka, 1994). Elliott *et al.* (1989) suggested that the initiation of CON phase is involving a full recruitment of all the major muscles of pectoralis major, the long head of triceps muscle group. However, the long head of the triceps muscle group is reported to be slightly delayed from the initiation of the ascend phase. Also, biceps brachii is reported to be frequently active at the start of the acceleration phase. Most often the biceps brachii bursts are short in duration of only 0.2s at average.

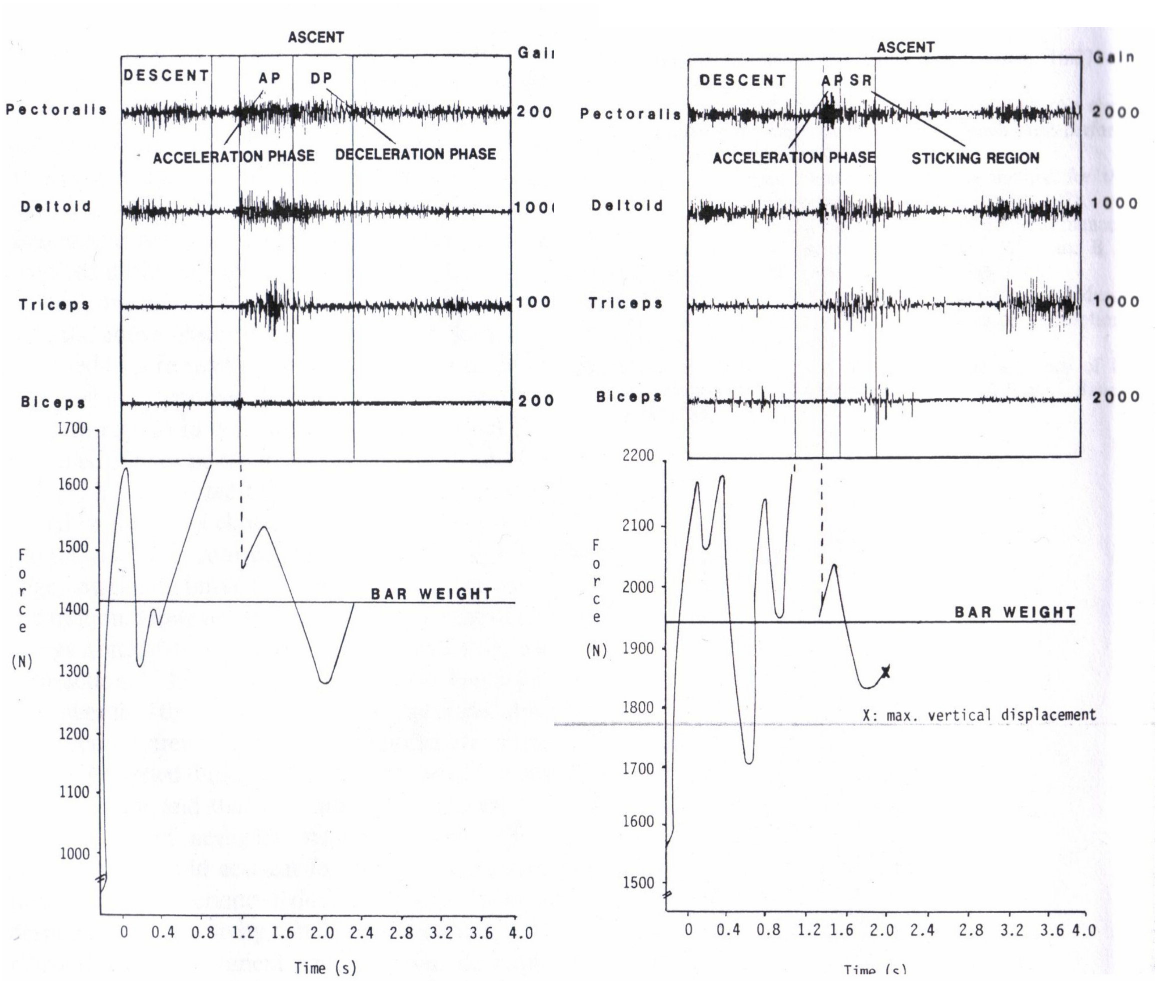

FIGURE 17. EMG and force-time curve from a successful 81% load performance (left) and an unsuccessful 104% performance (right) (Elliott *et al.*,1989).

The highest point of its activity is seen at the end of the sticking region and especially once high loads are applied. (Elliott *et al.*, 1989). In this the study of Elliott *et al.* (1989) three unsuccessful performances were recorded with 81% loading that were nearly identical in their movement patterns to a successful 100% loading condition. This resembles the fact that there are seemingly several other factors contributing to successful bench press performance beside recordable neuromuscular contributors.

In addition, the electromechanical delay value of 35ms is reported at each muscle tested that should be taken to the consideration in analysis of the data (Norman *et al.* 1979, and Ralston *et al.,* 1976). This delay has to be taken in to a consideration to synchronise force and EMG signals in order to make them corresponsive in time-frame. The sticking region can be seen to be extended in the unsuccessful lift with parallel shortened acceleration phase in both of the signals of EMG activity and force-time curve.

7.4. The role of SSC in bench press movement

When an individual performs according to the International Power-lifting Federation rules, the contribution of series elastic component diminishes in SSC action as the bar is remained steady at chest before the CON phase. The purpose of applying SSCs, or in other words, plyometric exercises is to favour the storage of elastic energy into series elastic component. This stored energy is utilised during the series elastic and contractile components shortening simultaneously (Enoka, 1994). Bench press movement is a multiple-joint movement involving SSC, but is affected by the technique used as discussed earlier. Regarding to Komi (2000), the main characteristic to SSC performance enhancement is to do with a very low EMG-activity in the CON phase of the cycle, and with emphasised contribution of short-latency stretch-reflex component.

Walshe *et al.* (1998) observed SSC squatting to result with greater work output compared to the work output in CON only (154.8 ± 34.7 and 129.7 ± 34.4 J respectively). In addition, work output after the SSC test over the first 300 ms from the start was observed to be significantly larger than that for the corresponding period in CON activity preceding ISOM pre activity ($P < 0.05$).

However, after fatiguing SSC exercising a muscle spindle disfacilitation and activation of III and IV afferent nerve endings may results with reduced stretch reflex sensitivity and muscle stiffness that will impair the force potentiation mechanism (Komi, 2000).

8 PURPOSE

The purpose of this study was to find the most efficient ECC-CON loading strategy for muscle hypertrophy by employing various DAER resistances in bench-press exercising. Various DAER resistances (CON: 70%; ECC: 80%, 90% and 100% of 1RM) were employed to detect the changes in force responses, muscle activation and in blood serum markers of La and GH. Acute responses of DAER exercising have not been previously studied extensively. This expanded the purpose of the study not only to examine the previously found responses of ECC and DAER exercising, but also to monitor the neuromuscular, hormonal and blood serum markers.

8.1. Hypotheses

Hypothesis0: There are no changes in maximum force, RFD, muscle EMG activity, or in antagonist co-activity in the experiment conditions compared to the control conditions.

Hypothesis1: There is greater average ECC muscle activation in all or in the greatest of the experimental loading conditions of 80%, 90% and/or 100% compared to the 70% loading condition.

Hypothesis2: Change in antagonist co-activation (ISOM bench-press) is significantly different in all or in the greatest of the experiment conditions (80%, 90% and 100%) compared to the control condition (70%).

Hypothesis3: The post measurement concentration of GH and/or La and the change in GH and/or in La level from pre to post stage are significantly greater in all or in the greatest of the experimental loading conditions of 80%, 90% and/or 100% compared to the increase observed in the 70% condition.

9 METHODS

9.1. Subjects

The subject group consisted of 11 physically active males with previous experience in resistance training. The subjects were healthy and their mean age was 32.4 ± 4.3years (mean ± SD). Mean BM and height were 86.3 ± 8.8kg and 177.8 ± 6.2cm and body mass index was 27.4 ± 0.6. Subjects were informed in detail of the research project, healthy questionnaire was filled and they also signed a written consent form before any measurements were taken. The protocol used in the present study was approved by an ethical committee. Also, the subjects were aware that they were allowed to withdraw from the study at any point, if they felt uncomfortable to continue. The subject group was chosen based on their bench-press maximum related to their own BM. Subjects were able to lift a resistance of 1.2-1.4 times their own BM. Prior the familiarisation period subjects were informed that any abuse of anabolic hormones or any other food supplement than regular pure protein or carbohydrate were prohibited throughout the duration of the study. Subjects were informed pre-testing of blood samples that may reveal any abused product.

9.2. Familiarisation period

Prior the first testing session, the subjects accomplished 6 weeks familiarisation training. The familiarisation included a total number of 5 resistance unsupervised exercise sessions in a gym (2 weeks) and 5 sessions (4 weeks) at a lab, where the subjects trained their maximum and explosive strength with DAER loads. As the subjects were constant visitors in a gym, the unsupervised 2 weeks familiarisation period was started with a relatively intensive hypertrophic session and it progressed towards maximum resistances at the end. The DAER maximum and explosive training period consisted of 4 maximum strength training sessions and 1 explosive training session where the subjects used various different DAER resistances. The subjects performed the same amount of DAER exercises prior the participation to the pre maximum strength testing session (prior the start of the measurements). The purpose of this extensive familiarisation period was to provide equated DAER training state for all of the subjects.

9.3. Maximum strength testing

The 1RM measurements were performed on separate sessions pre and post the participation to dynamic hypertrophical strength measurements. The loads that were used in dynamic hypertrophic strength measurements were determined by the pre maximum strength results for all of the subjects. The loads were assessed with a following formula: load $\%_{1RM}$ / 100 * 1RM, where 1RM is the maximum for one repetition and load $\%_{1RM}$ is 70, 80, 90, or 100. The outcome of this load determination equation was rounded to the closest bar load accuracy of 1.5 kilograms in ECC direction (the smallest discs used in weight releasers were 0.75kg), and to CON accuracy of 2.5 kilograms (the smallest discs used in the bar were 1.25kg).

9.4. Dynamic hypertrophic strength measurements

A dynamic hypertrophical strength protocol is provided in table 1. The sessions A, B, C and D were performed in inter-individually randomised order. The alteration was needed to avoid the occurrence of a familiarisation effect in the results. The subjects were instructed to perform dynamic bench-presses 4 sets x 10 repetitions. Between each set a 2-minute brake was held and the subjects were instructed to sit on a bench for that time. The CON resistance remained in all of the three measurement conditions at 70% of 1 CON RM. Eccentric loadings were 70%, 80%, 90% and 100% of 1RM. Two blood serum samples were collected for lactate and GH hormone determination during one visit to the laboratory. One of them was collected pre and another at post stage of the 4 dynamic sets to allow comparisons between the loading conditions. The first sample was taken after 3 minutes of quiescent sitting on a bench post the first ISOM bench press measurement. If the subject failed to lift the resistance one CON lift was assisted and the subject was given a change to try one more repetition. After a consecutive failed repetition the measurement was aborted and post blood samples were collected within 1 minute from the abortion. In the experimental condition sets, the weight releaser hooks detached from the bar after each descend (ECC) and were returned on the bar after the bar stopped ascending (CON). This process was used in order to maintain the greater resistance during ECC compared to CON at each repetition. Any cheating from the appropriate bench pressing technique was leading to a warning and finally to an abortion of the measurement. Muscular activity was measured during all of the 4 conditions to monitor both ECC and CON agonist and antagonist activation.

9.5. ISOM testing

Maximum activation of elbow flexor muscles was measured in ISOM MVC bicep curl test. Maximum ISOM bench press measurements were done pre and post the dynamic bench-pressing, such that 2 ISOM presses were performed pre and only 1 post the dynamic bench presses (table 1). A control elbow angle of 90º was used for isometric bench press measurements. The arms were controlled to be 90º abducted and to be maintained on the frontal plane. ISOM biceps brachii maximum muscle activation was measured for antagonist co-activation post all the dynamic hypertrophic strength measurements.

TABLE 1. Dynamic hypertropic strength testing protocol (* = *Lactate, GH collections*). One session was consisted of 2x1 maximum ISOM bench presses, 4 x dynamic sets, and again 1 maximum ISOM bench press.

Session A	2 x ISOM	*	4 x (max 10) x ECC 70% / CON 70%RM	*	1 x ISOM
Session B	2 x ISOM	*	4 x (max 10) x ECC 80% / CON 70%RM	*	1 x ISOM

Session C	2 x ISOM	*	4 x (max 10) x ECC 90% / CON 70%RM	*	1 x ISOM
Session D	2 x ISOM	*	4 x (max 10) x ECC 100% / CON 70%RM	*	1 x ISOM

9.6. Weight releasers

The variable resistance was produced by the help of weight releasers (appendix 1, Figure 40) in this study. Doan *et al.* (2002) applied additional ECC load by additional devices called weight releasers to a bench-pressing movement. The weight releasers have the potential to maximize the resistance in the ECC phase and to reduce it in the CON phase of the movement. This could be called as “eccentrical overload”. An illustration of weight releasers is presented in figure 18. The weight releaser is detached from the weight-lifting bar at the end of the ECC phase of the movement once the CON phase can be performed with lower resistance. As illustrated in the figure 18, the releasers detach from the bar and remains at the floor after the performance. In the hypertrophic measurements a multiple number of repetitions were needed to be “eccentrically overloaded”. Therefore, an assistant was needed to return the weight releasers on the bar after the repetition for consecutive repetitions.

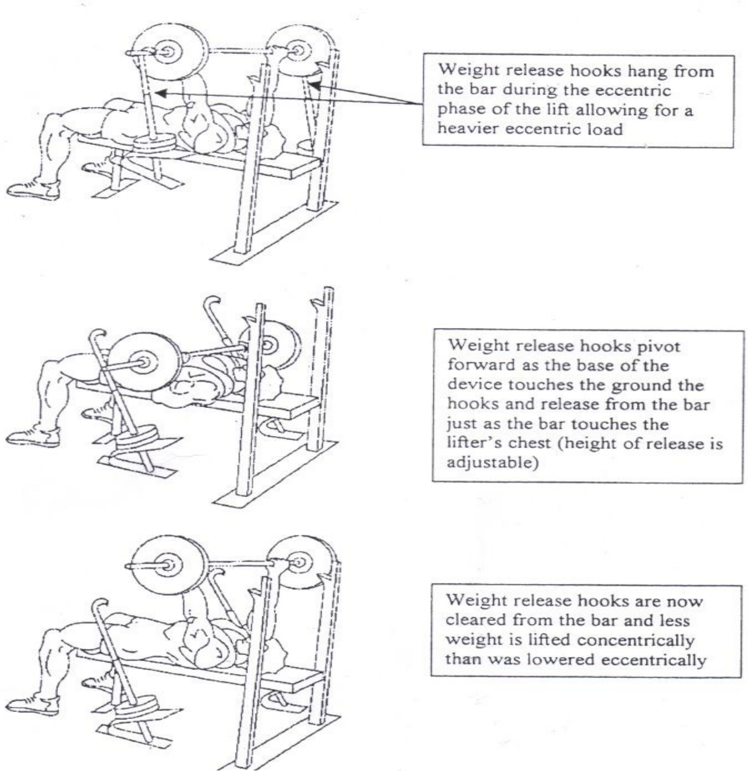

FIGURE 18. A weight releaser method (Doan *et al.*, 2002).

9.7. Surface electromyography

For the EMG measurements the skin was prepared at the electrode locations. After skin preparation of shaving and abrading with antiseptic alcohol and skin impedance was monitored to be less than 20kΩ. Bipolar surface EMG electrodes were assigned according to SENIAM 1999 guidelines for the medial portion of the triceps brachii (TB), medial deltoid anterior (DA), and pectoralis major (PA) muscles. To measure the degree of antagonist muscle activation, EMG signal was obtained also from the biceps brachii (BB) muscle. As the electrode location at pectoralis major muscle have varied in previous studies various electrode locations were tested in a pilot session to determine the most effective place for recording. As a result the electrode location at pectoralis major was determined regarding to Cogley et al. (2005). The pectoralis major electrode was placed at a point one third of the distance between the anterior aspect of the acromion and the xiphoid process. The determined electrode locations were marked with small ink-tattoo dot after the first visit to the laboratory for consecutive visits.

The EMG electrodes were connected directly to the small preamplifiers located approximately 10 cm from the recording site. The signals were led through shielded wires to telemetric Noraxon Telemyo 2400T V2 transmitter, with a bandwidth of 10–10000 Hz and a common mode rejection ratio >100 dB. EMG signal was captured then by Noraxon 2400R receiver from where it was transferred to signal processing analogue to digital converter and to the actual recording unit. EMG signal was rectified and band pass filtered according to the recommendations of SENIAM 1999.

9.8. Venous blood samples

Venous blood samples were collected pre and post hypertopic bench pressing sets for GH and La concentration determination. The samples were collected either from the right or left arm. Two cuvettes of blood were collected during one visit to laboratory (one measurement). The first one of the samples was collected right before the start of first hypertropic set and the last sample one minute post the fourth set (last set).

9.9. La analysis

Lactate analysis was processed by Stat Profile® pHOx® Plus L- analyzer (Nova Biomedical, MA, U.S.A.). Whole blood sample was colleted to Venosafe Li-heparin tube where entzyme/amperometric lactate analysing method was applied on the lactate samples.

9.10. Serum GH analysis

GH analysis was processed in the Immulite 1000 automated immunoassay analyser into Venosafe gel tube. The immulite 1000 system utilises assay-specific, antibody or antigen-coated plastic beads as solid phase, alkaline phosphatase-labeled reagent, and a chemiluminiscent enzyme substrate in determination of hGH concentration.

9.11. Joint angle measurement

To determine joint angle displacement and velocity an electronic goniometer (Department of Biology of Physical Activity, Jyväskylä) was used. The goniometer was adjusted at the elbow joint and it was connected to the computer through signal processing analogue to digital converter. The goniometer was located such that the other shaft of it was in line with humerus and another in line with radius. The mid flipping point of the goniometer was located on the top of the lateral epicondyle of humerus. The goniometer signal was low-pass filtered at 20Hz frequency.

9.12. Bar displacement and velocity

Bar displacement and velocity was determined using ultrasonographic Axon device. The Axon was located perpendicularly under the weight bar at the starting position of the movement. The recording started from the starting point, where the subject was supine laying and holding the bar on the hands with the extended elbow joints.

9.13. Bench pressing technique

All the performances were done in supine laying, while maintaining the legs lifted up to 90º hip angle. An “arched back” or bouncing from the chest was not allowed requiring the subjects to move the bar only by forceful contraction. Also, the grip was controlled such that the thumb was required to go around the bar. In other words, a so called ‘thump lock’ was not allowed. The subjects were instructed to choose the grip width on the bar that is wider than shoulder width. The final adjustment to the grip width was done by the subject and then the chosen width was marked on the bar and kept for the consecutive testing sessions. The grip width was marked on the bar by tape marks. In explosive measurements the bar was kept in the starting position between the repetitions for approximately 1 second. The location of the subject's head on the bench was standardised such that the place remained the same from measurement to measurement. A repetition started from a position, where subject held the bar on his hands with straight elbows. The bar was expected to be lowered to a vertical distance of 0.5-1.0cm on the top of the tip of a sternum (xiphoid process) at the lowest bar position.

9.14. Statistical analysis

The data are given as group of mean±SEM. 4-factorial repeated measures of ANOVA ($P<0.05$) was applied to all absolute, absolute change and relative change of force, velocity, EMG and blood sample data for statistical significances within and between the group means. Also two-tailed pairwise comparisons t-test ($P<0.05$) was applied for significances between individual greatest La and GH value comparisons to the control values, La and GH mean values, La and GH divided by number of repetitions data, exercise duration and number of repetitions data. In addition t-test was applied on group greatest La and GH values comparisons to the control condition. Pearson-r correlation ($P<0.05$) was applied for correlations of La change to 1RM, and La change to 1RM/BM.

10 RESULTS

Tables 2 and 3 provide La and GH pre, post and change. The greatest La and GH post concentrations were observed in two of the highest conditions of 90% and 100% (table 2 and 3), but no significant difference was observed between the loading conditions. Also, greatest La and GH change concentrations occurred in 90% and 100% conditions (table 2 and 3).

Table 2. Mean (Mean±SEM) La absolute values (mmol/l) and the La change from pre to post measurement in each of the conditions (mmol/l).

70 %	pre	post	change	80 %	pre	post	change	90 %	pre	post	change	100 %	pre	post	change
Mean	**2.5**	**10.2**	**7.8**		**2.7**	**11.0**	**8.3**		**2.6**	**12.1**	**9.5**		**2.6**	**11.8**	**9.2**
SEM	0.1	0.5	0.4		0.2	0.5	0.4		0.2	0.5	0.5		0.1	0.5	0.4

Table 3. Mean (Mean±SEM) GH absolute values (mlU/l) and the GH change from pre to post measurement in each of the conditions (mlU/l) (n = 7).

70 %	pre	post	change	80 %	pre	post	change	90 %	pre	post	change	100 %	pre	post	change
Mean	**1.2**	**3.5**	**2.4**		**1.4**	**4.7**	**3.3**		**3.2**	**8.7**	**5.5**		**2.0**	**6.8**	**4.9**
SEM	0.3	1.5	1.1		0.6	1.9	1.3		1.0	3.1	2.3		0.7	2.0	1.5

Table 4 provides mean duration and mean number of repetitions at each of the 4 conditions. Table 5 provide 1RM results at pre and post participation to the experiment. 1RM changes from pre to post 1RM measurement, and 1RM/BM ratio at pre and post experiment are provided in table 5. A significant increase ($p<0.05$) in 1RM occurred from pre to post measurement.

Table 4. Duration (time used to exercising in a condition in seconds) and number of repetitions during the 4 sets (Mean±SEM).

Condition	**70%**	**80%**	**90%**	**100%**
Duration (s)	91.6±3.9	104.1±2.4	99.9±2.1	106.4±2.6
Repetitions	35.7±1.0	35.0±1.0	33.4±1.2	30.6±1.2

Table 5. 1RM prior and post the experiment (kg), 1RM change (± kg) from pre to post 1RM measurement, 1RM/BM ratio pre and post experiment.

	1RM (kg)		**1RM CHANGE**	**1RM/BM**	
	pre	post		pre	post
Mean	**108.3**	**110.0***	**1.7**	**1.3**	**1.3**
SEM	3.8	3.8	0.5	0.0	0.0

Significant difference compared to control condition of 70%,*p<0.05.

The preferred ECC load expressed by La change concentration was 86.2 ± 2.2% of CON 1RM (n=8, Mean ± SEM). The preferred load expressed by GH change concentration was 90 ± 2.1% of CON 1RM (n=7, Mean ± SEM).

10.1. Metabolic results

Mean La concentration did not show significant differences between the conditions. The post measurement lactate concentrations of 70%, 80%, 90% and 100% conditions were 10.23±0.45, 10.99±0.50, 12.12±0.55 and 11.77±0.51mmol/l, respectively. La concentration was significantly increased (p<0.001) from pre to post measurement in all of the conditions of 70%, 80%, 90% and 100% (figure 19).

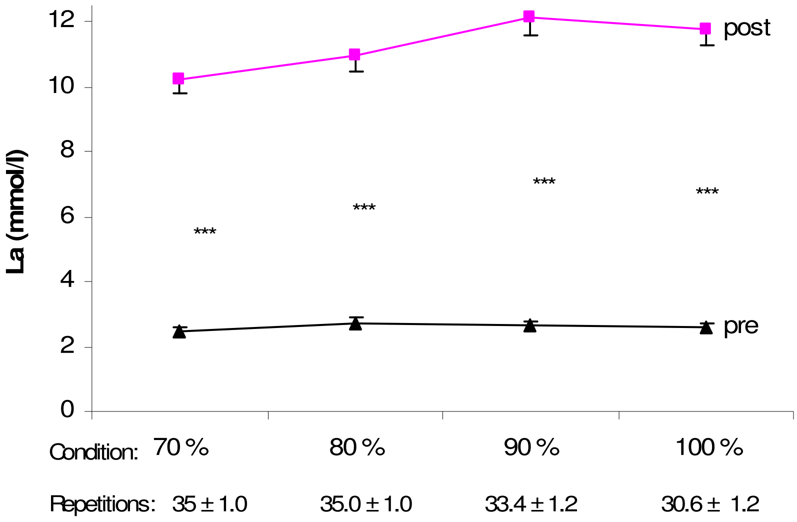

FIGURE 19. Mean (±SEM) absolute La concentration (mmol/l) at pre and post measurements in each of the 4 conditions (average ± SEM). Number of repetitions performed at each of the condition (ECC %1RM) at the bottom of the figure. Subjects were instructed to perform 4 x 10 repetitions = 40 repetitions in each of the conditions. Significant difference between all pre and post conditions,***p<0.001

Mean La concentration at post measurements divided by the mean number of repetitions performed in the condition showed no significant differences between the conditions. Significant differences were observed between all the pre and post La measurements (p<0.001). The La concentration in the control condition (70%) was 0.30±0.02mmol/l/repetition, and in the experiment conditions of 80%, 90% and 100% the post La concentration was 0.32±0.02, 0.39±0.03, and 0.417±0.03mmol/l/repetition, respectively (average ± SEM) (figure 20). However, in the both figures 19 and 20, a trend towards greater La concentrations was observed to occur once greater loads were applied (two of the highest experiment conditions of 90% and 100%).

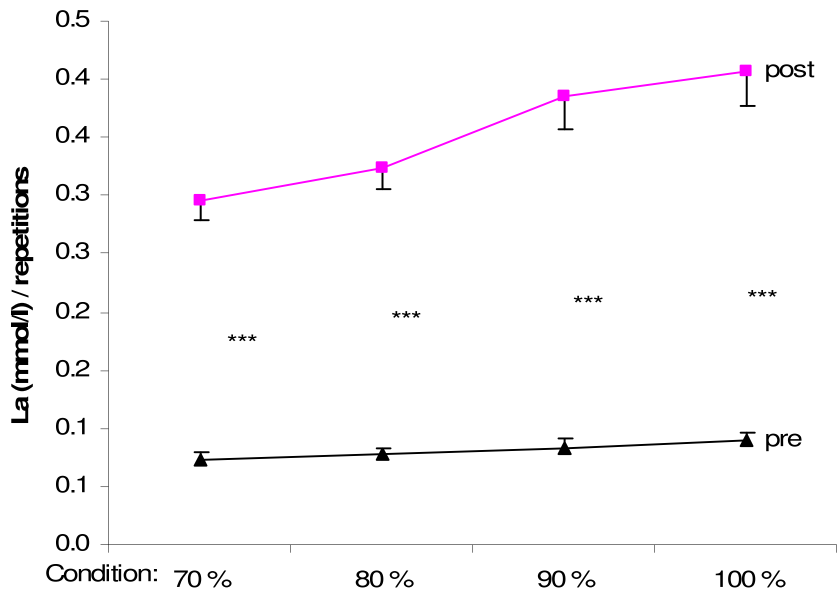

FIGURE 20. Mean La concentration (Mean ± SEM) at pre and post measurements divided by repetitions (mmol/l/repetition). Derived by: individual La / individual repetitions = individual La accumulation during 1 repetition → Mean La. Significant difference between all pre and post conditions,***p<0.001,

There were no significant differences in absolute mean pre and post GH concentrations at any conditions (figure 21). The post GH levels in all of the 4 conditions of 70%, 80%, 90% and 100% were 3.53±1.46, 4.70±1.88, 8.69±1.88, 6.84±2.01mlU7l, respectively (average ± SEM).

No significant differences were observed in mean GH concentrations divided by repetitions (figure 22). The GH concentration in the control condition (70%) was 0.067±0.04mlU/l/repetition, and in the experiment conditions of 80%, 90% and 100% the post GH concentrations were 0.075±0.04, 0.161±0.09, and 0.140±0.05mlU/l/repetition. However, in both of the figures 21 and 22 a trend to greater GH concentrations occurred in two of the highest experiment conditions of 90% and 100%.

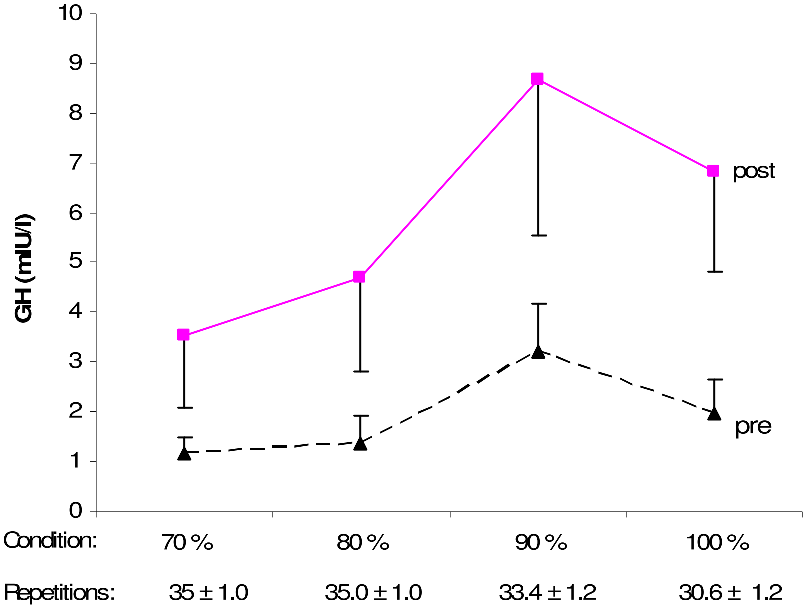

FIGURE 21. Mean (±SEM) GH concentration at pre and post conditions. Number of repetitions performed at each of the condition (ECC load presented, % CON 1RM) at the bottom of the figure. Subjects were instructed to perform 4 x 10 repetitions = 40 repetitions in each of the conditions.

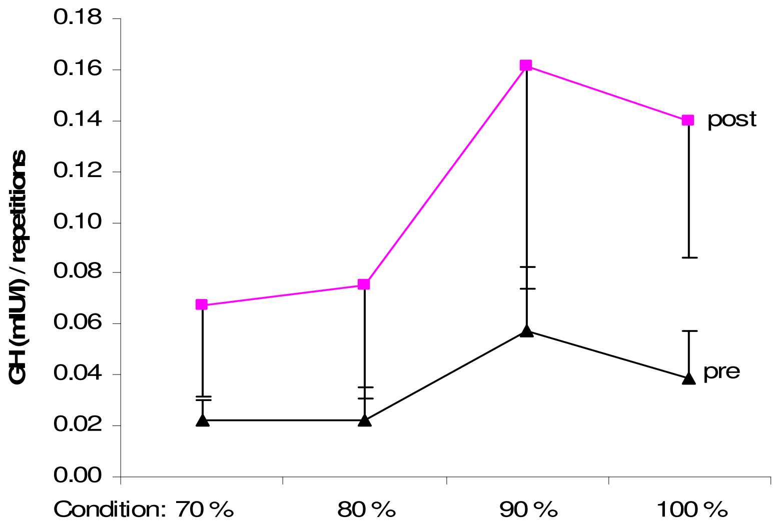

FIGURE 22. Mean (±SEM) absolute GH concentration at pre and post measurements divided by repetitions (mlU/l/repetition). Derived by: individual GH / individual repetitions = individual GH accumulation during 1 repetition → Mean GH during 1 repetition.

Figure 23 presents mean change (from pre to post measurement) concentrations of GH and La in the conditions of 70% and 90%. The change in La concentration was significantly different ($p<0.05$) in 70% from that of 90% (7.7±1.15 vs. 9.5±2.33mmol/l, respectively). No significant difference was observed in GH change between the conditions of 70% and 90%. The GH change were in 70% and 90% conditions 2.36±0.43 and 5.46±0.49mlU/l, respectively.

Figure 24 illustrates the change at 70% condition in La and GH compared to the observations obtained from the conditions where the greatest individual GH and La change occurred (x/70). La change level was significantly different between 70/70 (70%) and x/70% ($p<0.001$). The La change in 70/70 (70%) and x/70 (x/70%) conditions were 7.78±0.43 and 10.75±0.38mmol/l, respectively (average ± SEM). No significant difference in GH concentration between 70/70 (70%) and x/70 (x/70%). The GH change in 70/70 (70%) and x/70 (x/70%) conditions were 2.36±1.15 and 8.19±2.5mlU/l, respectively.

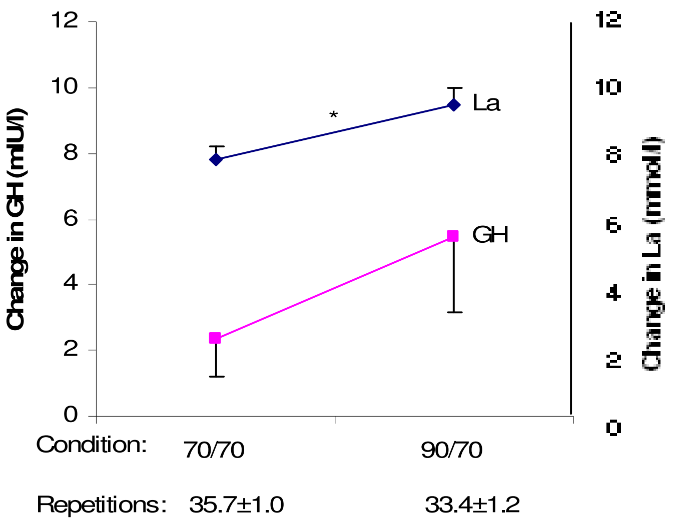

FIGURE 23. Mean (±SEM) change in La and GH concentrations in the control condition (70%/70% 1RM) compared (pair-wise comparisons) to the highest experiment condition of 90%/70% (average ± SEM). The mean number of repetitions is given at the bottom of the figure (average ± SEM). Significant difference in La, *$p<0.05$.

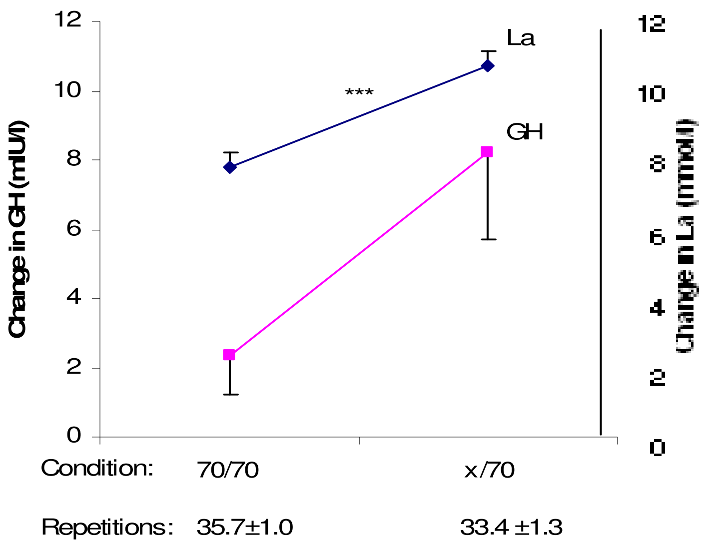

FIGURE 24. Mean (± SEM) change in La and GH concentrations in the control condition (70%/70% 1RM) compared (pair-wise comparisons) to the highest individual La and GH concentration condition (x /70%). The mean number of repetitions is given at the bottom of the figure. Significant difference, ***p<0.001.

10.2. Force

The pre and post ECC mean force measured during 500ms as the subject passes the elbow angle of 90° is illustrated in figure 25. Significant differences were found to the control condition of 70% in all the pre measurement conditions of 80% (P<0.01), 90% (P<0.01) and 100% (P<0.001). The pre ECC force levels at 70%, 80%, 90% and 100% conditions were 796.6±43.4, 872.3±47.7, 948.4±51.4 and 1014.3±55.7N, respectively.

In addition, there were significant differences (P<0.001) in comparison to the control condition of 70% in all the post measurement conditions of 80%, 90% and 100%.

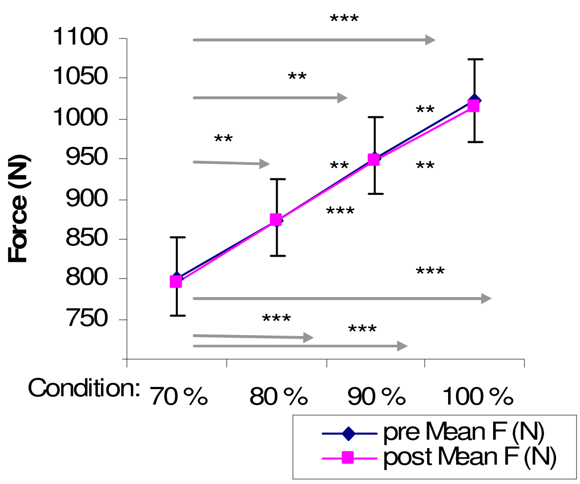

FIGURE 25. Mean (± SEM) ECC force (N) (500ms around 90° elbow angle), *p<0.05, **p<0.01,***p<0.001.

No significant differences were found between the conditions in mean CON force measured during 500ms as the subject passes the elbow angle of 90° (figure 26). Significant differences were found between all the pre and post measurements (P<0.001).

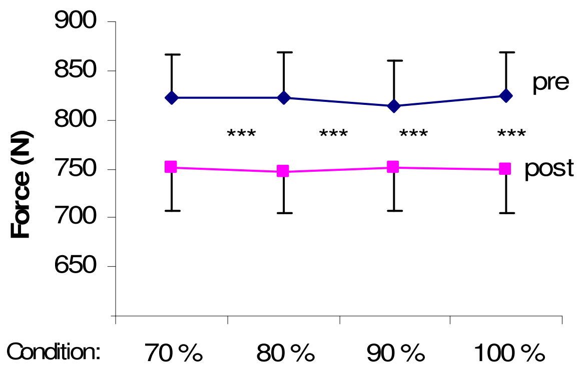

FIGURE 26. Mean (± SEM) CON force (N) (500ms around 90° elbow angle), ***p<0.001.

No significant differences were observed between the conditions in ISOM peak force as illustrated in figure 27. However, significant differences were observed between all the pre and post measurements (P<0.001).

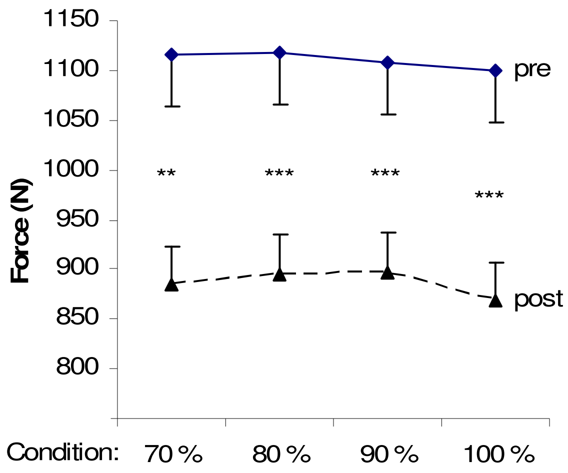

FIGURE 27. Mean (± SEM) ISOM peak (500ms around peak F exertion) force at pre and post measurements, **p<0.01, ***p<0.001.

10.3. EMG

10.3.1. Absolute ECC mean EMG activity

The pre and post ECC mean EMG activation was measured during 500ms as the subject passes the elbow angle of 90°. No significant differences were observed between the conditions in the pectoralis major, nor in triceps brachii ECC mean EMG activity as illustrated in figure 28. However, significant differences were seen between pre and post mean EMG activity levels of pectoralis major in the conditions of 70%, 80% and 90% (P<0.05).

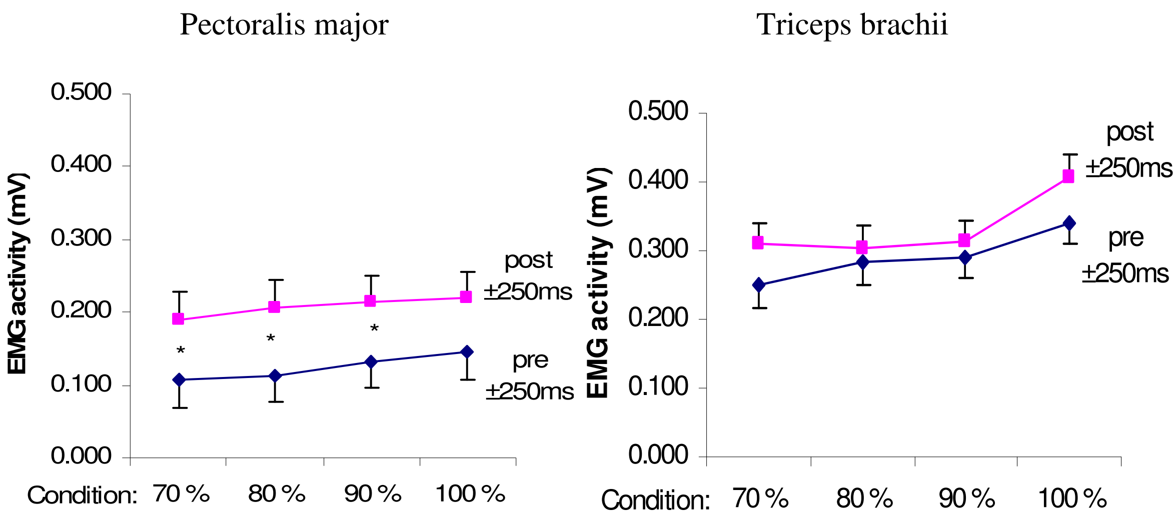

FIGURE 28. Left: Mean (± SEM) ECC pectoralis major EMG activity (±250ms at 90°). Significant difference between rep 2 and rep x, *p<0.05. Right: Mean (± SEM) ECC triceps EMG activity (±250ms at 90°).

Significant differences were recorded between the 70% and 90% conditions (P<0.001), and also between conditions of 70% and 100% (P<0.01) in deltoid anterior ECC mean EMG activity as illustrated in figure 29. No significant differences were observed between the pre and post condition.

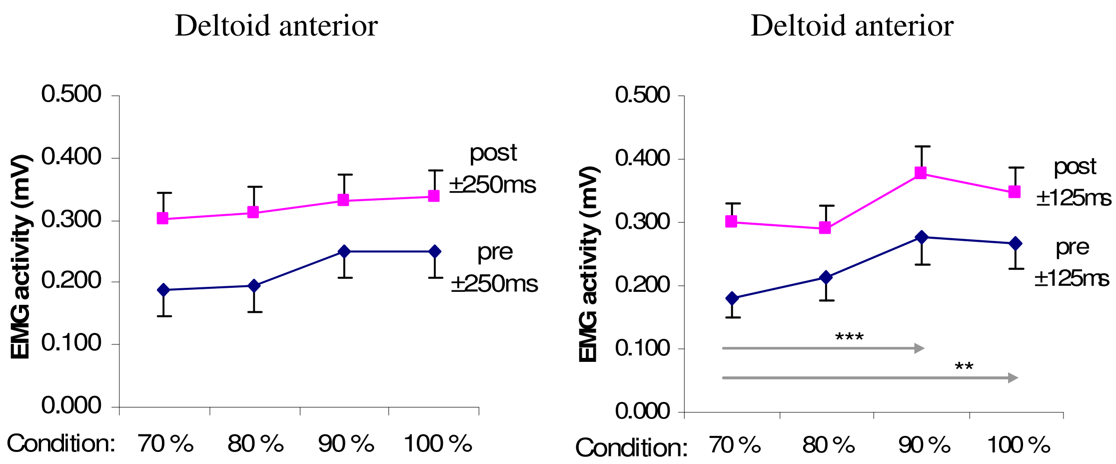

FIGURE 29. Left: Mean (± SEM) ECC deltoid EMG activity (±250ms at 90°). Right: Mean (± SEM) ECC deltoid EMG activity (±125ms at 90°). Significant difference compared to control condition of 70%/70% in pre stage, **p<0.01,***p<0.001.

No significant differences were observed between the conditions, or between pre and post measurements in biceps brachii ECC mean EMG activity as illustrated in figure 30.

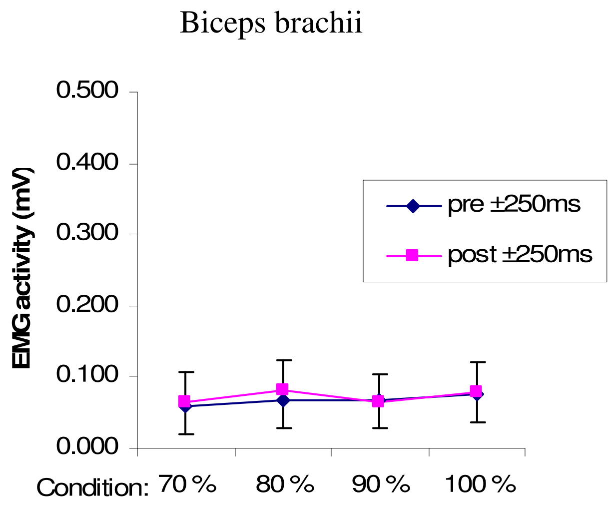

FIGURE 30. Mean (± SEM) ECC bicep EMG activity (±250ms at 90°).

10.3.2. CON absolute mean EMG activity

The pre and post CON mean EMG activation was measured during 500ms as the subject passes the elbow angle of 90°. No significant differences were observed between the conditions, or between pre and post measurements in pectoralis major and in triceps brachii CON mean EMG activity as illustrated in figure 31.

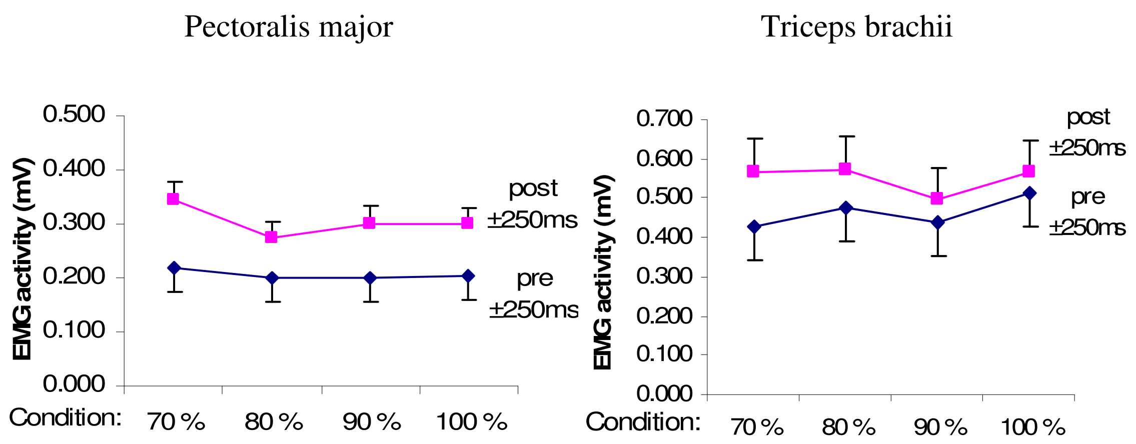

FIGURE 31. Left: Mean (± SEM) CON pectoralis major EMG activity (±250ms at 90°).
Right: Mean (± SEM) CON triceps mean EMG activity (±250ms at 90°).

No significant differences were observed between the conditions or between pre and post measurements in the deltoid anterior and in biceps brachii CON mean EMG activity as illustrated in the figure 32.

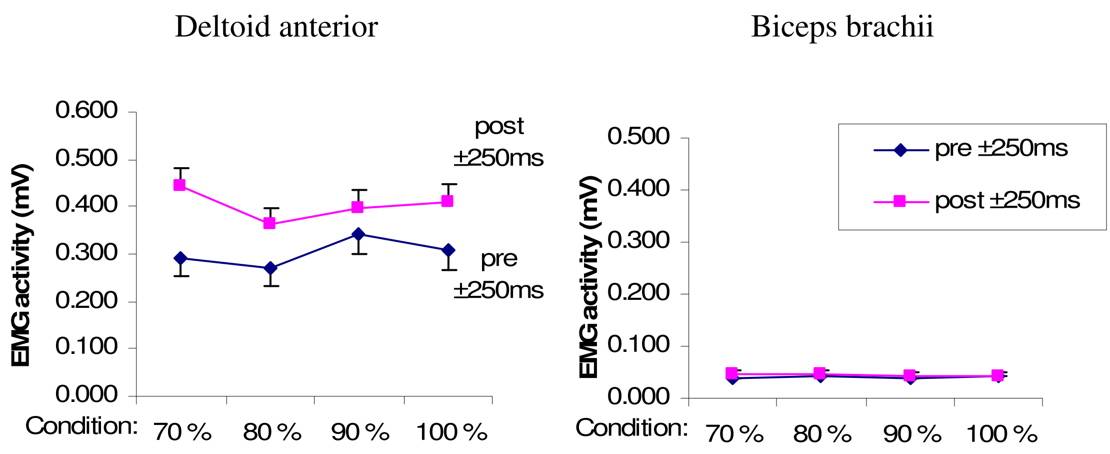

FIGURE 32. Left: Mean (± SEM) CON deltoid EMG activity (±250ms at 90°).
Right: Mean (± SEM) CON biceps brachii EMG activity (±250ms at 90°).

10.3.3 ISOM absolute EMG activity

The pre and post ISOM mean EMG activation was measured during 500-1500ms from the start of ISOM force exertion. No significant differences were observed between the conditions or between pre and post measurements in the pectoralis major and in triceps brachii CON mean EMG activity as illustrated in figure 33.

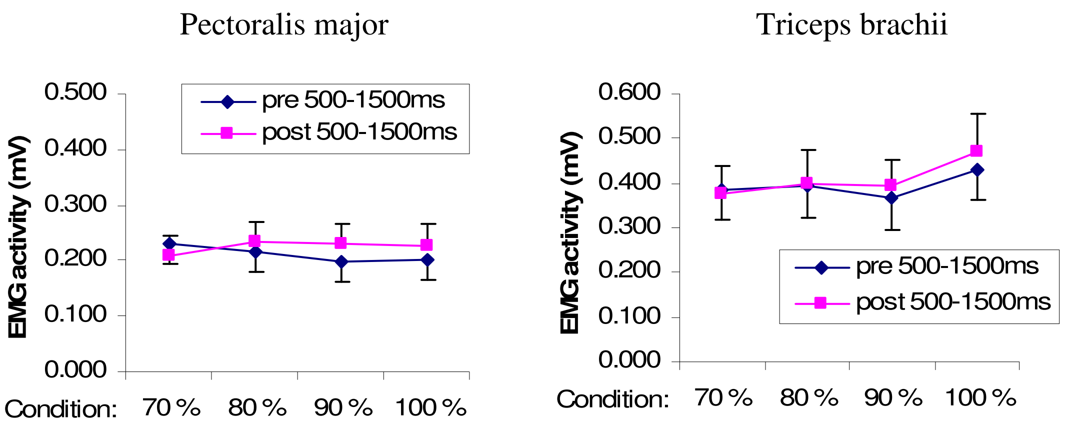

FIGURE 33. Left: Mean (± SEM) ISOM pectoralis EMG activity. Right: Mean (± SEM) triceps EMG activity activity (500-1500ms from the start of a contraction).

No significant differences were observed between the conditions, or between pre and post measurements in the deltoid anterior and in biceps brachii CON mean EMG activity as illustrated in figure 34.

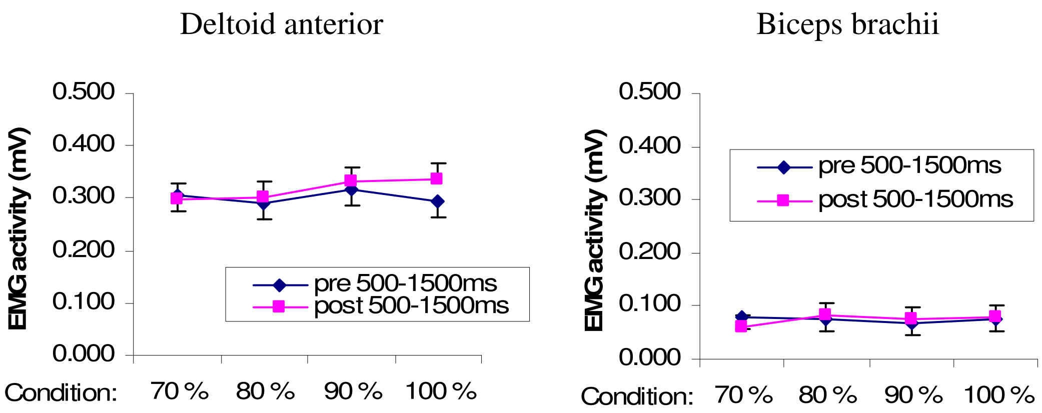

FIGURE 34. Left: Mean (± SEM) ISOM deltoid EMG activity. Right: Bicep ISOM EMG activity (500-1500ms from the start of a contraction).

10.4. Antagonist co-activity

The pre and post ECC mean antagonist co-activation of biceps brachii was measured during 500ms as the subject passes the elbow angle of 90°. No significant differences were observed between the conditions, or between pre and post measurements as it is illustrated in the figure 35.

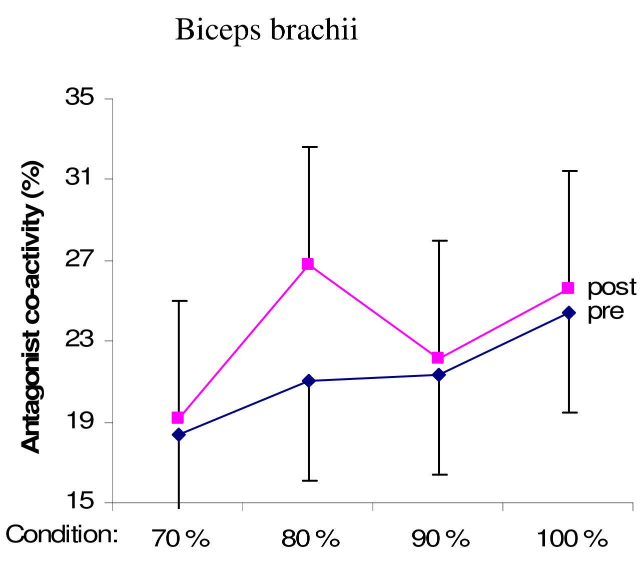

FIGURE 35. Mean (± SEM) ECC antagonist co-activity (±250ms at 90°).

The pre and post CON mean antagonist co-activation of biceps brachii was measured during 500ms as the subject passes the elbow angle of 90°. No significant differences were observed between the conditions, or between pre and post measurements as illustrated in the figure 36.

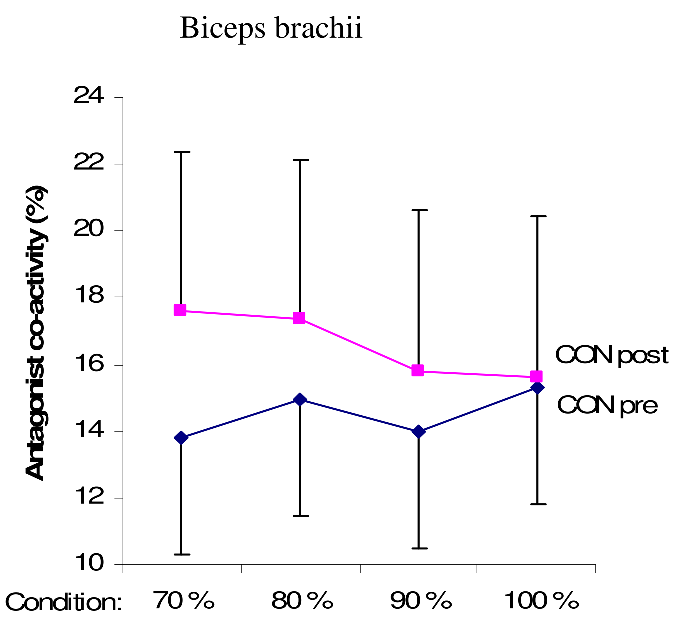

FIGURE 36. Mean (± SEM) CON antagonist co-activity (±250ms at 90°).

The pre and post ISOM mean antagonist co-activation of biceps brachii was measured during 500ms around peak ISOM force output. No significant differences were observed between the conditions or between pre and post measurements as illustrated in the figure 37.

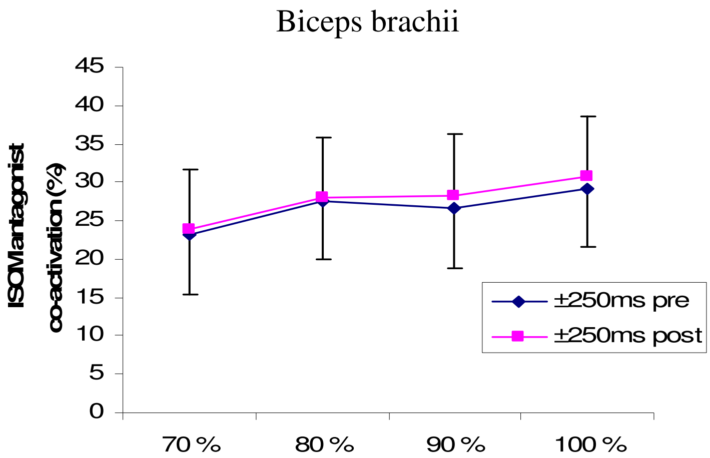

FIGURE 37. Mean (± SEM) ISOM antagonist co-activation in pre and post measurements (±250ms at peak force).

10.5. RFD

The pre and post mean RFD was measured during the first 300ms at the start of ISOM force output. No significant differences were observed between the conditions, or between pre and post measurements as illustrated in the figure 38.

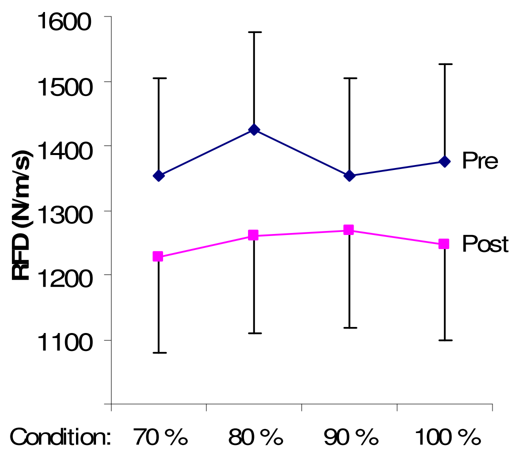

FIGURE 38. Mean (± SEM) RFD in ISOM pre and post bench press measurements.

10.6. Velocities

No significant differences were observed between the conditions or between pre and post measurements in ECC mean bar velocity, mean elbow angle velocity nor in peak ECC elbow angle velocity. The mean ECC values of mean bar velocity, mean elbow angle velocity and peak elbow velocity are provided in the table 6. Significant differences were observed between pre and post measurements in CON mean bar velocity, mean elbow angle velocity and in peak ECC elbow angle velocity ($P<0.001$). However, no significant differences were found between the conditions. Pre and post values of CON mean bar velocity, mean elbow angle velocity and peak elbow angle velocity are given in table 7.

TABLE 6. ECC mean (± SEM) bar, mean elbow angle and peak elbow angle velocity at pre and post measurements (from the start of ECC phase to stop of bar descending at chest).

Condition	Bar mean (± SEM) (m/s)	Mean elbow (± SEM) (deg/s)	Peak elbow (± SEM) (deg/s)
70/70 pre	**-0.41±0.04**	**8.0±4.6**	**432.7±13.0**
80/70 pre	**-0.38±0.02**	**12.0±2.7**	**424.90±8.8**
90/70 pre	**-0.36±0.02**	**6.5±4.1**	**417.7±10.1**
100/70 pre	**-0.31±0.03**	**0.7±2.2**	**397.0±10.5**

Condition	Bar mean (± SEM) (m/s)	Mean elbow (± SEM) (deg/s)	Peak elbow (± SEM) (deg/s)
70/70 post	**-0.37±0.02**	**5.0±1.2**	**418.5±10.4**
80/70 post	**-0.36±0.02**	**5.3±1.4**	**404.40±8.9**
90/70 post	**-0.32±0.02**	**3.6±1.0**	**399.5±12.4**
100/70 post	**-0.32±0.03**	**2.6±0.03**	**375.4±12.5**

TABLE 7. CON mean (± SEM) bar, mean elbow angle and peak elbow angle velocity at pre and post measurements (from the start of ECC phase to stop of bar descending at chest). Significant difference to pre values, ***p<0.001.

Condition	Bar mean (± SEM) (m/s)	Mean elbow (± SEM) (deg/s)	Peak elbow (± SEM) (deg/s)
70/70 pre	**0.41±0.04**	**32.1±1.3**	**212.0±10.4**
80/70 pre	**0.43±0.01**	**32.3±0.7**	**198.00±6.2**
90/70 pre	**0.44±0.01**	**31.7±0.8**	**196.60±8.8**
100/70 pre	**0.44±0.01**	**30.2±0.8**	**186.90±6.9**

Condition	Bar mean (± SEM) (m/s) ***	Mean elbow (± SEM) (deg/s) ***	Peak elbow (± SEM) (deg/s) ***
70/70 post	**0.15±0.02**	**18.0±0.9**	**96.30±7.6**
80/70 post	**0.15±0.02**	**18.1±0.4**	**90.3±11.8**
90/70 post	**0.15±0.02**	**16.7±1.4**	**98.70±7.9**
100/70 post	**0.16±0.02**	**16.8±0.5**	**81.90±6.4**

10.7. Correlations

High correlation coefficients were observed between preferred load by lactate and 1RM/BM-ratio (R=0.851, P<0.05); preferred load by lactate and pre experiment 1RM (R=0.821, P<0.05); preferred load by lactate and 1RM pre the actual hypertrophic measurements (R=0.881, P<0.05); and between preferred load by lactate and post hypertrophic measurements (R=0.874, P<0.05), table 8. The correlation between preferred load by lactate and 1RM/BM-ratio is illustrated in the figure 39. The correlations coefficients for preferred load by lactate and pre experiment 1RM; preferred load by lactate and 1RM pre the actual hypertrophic measurements; and preferred load by lactate and post hypertrophic measurements are given in table 8.

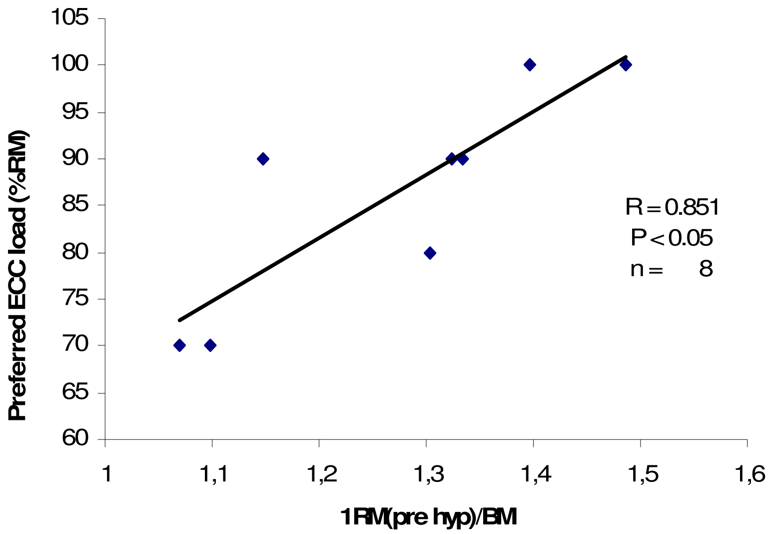

FIGURE 39. Relationship between preferred ECC load determined by lactate change (ECC % 1RM) and 1RM/BM ratio.

Table 8. Selected correlation coefficients, p<0.05 (r-values >0.80 bolded).

Correlations with subjects' individual values:			
Pref. ECC load (%) by La	vs	1RM (post HYP)	**0.874**
Pref. ECC load (%) by La	vs	1RM (prior HYP)	**0.881**
Pref. ECC load (%) by La	vs	1RM/BM	**0.851**
Pref. ECC load (%) by La	vs	1RM (prior participation to test)	**0.821**
Change in GH in 70/70	vs	change in La in 70/70	0.015
Change in GH in 80/70	vs	change in La in 80/70	-0.025
Change in GH in 90/70	vs	change in La in 90/70	-0.528
Change in GH in 100/70	vs	change in La in 100/70	-0.368
Individual change in GH	vs	Individual change in La	0.093
Correlations with mean values:			
Change in mean GH (%)	vs	change in mean La (%)	-0.356
Change in mean GH	vs	change in mean La	**1.000**
ECC load (% 1RM)	vs	mean Δ in GH	**0.882**
ECC load (% 1RM)	vs	Δ in mean La	**0.880**
ECC load (%1RM)	vs	Δ in mean La	0.255

11 DISCUSSION

One of the major findings of the present study was the significant difference observed in La change from pre to post measurement in the 90% condition. The significant difference observed between the individual control condition La change and the individual highest La change response can be regarded as another of the primary findings. In addition the similar trends seen in La and GH concentrations may be important findings as well. Furthermore, the EMG responses provided indications of individual muscle function as a response to DAER and isoinertial exercising. The present study provided also suggestions towards the determination of resistances used in DAER exercises. The individualised DAER loading suggestions were based on the correlation obtained from individual 1RM/BM and the condition with the highest individual La change response (preferred ECC load by La). The observations of RFD, bar velocity and elbow angle velocity did not show any significant differences between the conditions and therefore none of them were of major importance in the present DAER "hypertrophic" loading study.

11.1. Endocrinology

Since no significant differences were observed between the conditions in La findings (La post concentration, La change, and in La change per 1 repetition) the observations could only indicate the increase in ECC resistance in the present study. However, there could be a number of alternative reasons to explain the changes in post La, La change and in 1 repetition based La level. The increases in the three previous La values could be seen to originate from the increased ECC load due to the trends seen in La and GH change values, in post values and in change pre 1 repetition values were seen to increase from the 70% condition towards the heavier conditions of 90% and 100%. For instance, post levels of lactate at the conditions of 70%, 80%, 90% and 100% were 10.23±0.45, 10.99±0.50, 12.12±0.55 and 11.77±0.51mmol/l, respectively (figure 19). In addition, the perception of metabolic response increases in accordance to the increasing load can be further emphasized as the increase in a number of repetitions did not seem to lead to a concurrent increase in post levels of La (the number of repetitions at conditions of 70%, 80%, 90% and

100% were 35.7±1.0, 35.0±1.0, 33.4±1.2 and 30.6±1.2, respectively). The observation of La change per 1 repetition (figure 20) provide more exact data compared to absolute La observations as the La production could be influenced by the number of repetitions performed during DAER exercising. Therefore the metabolic response observation by La and GH is expectedly the most valid when it is associated with the number of repetitions (La change per 1 repetition). This is because the increases in serum metabolic markers, especially GH, appear to be the greatest during variable hypertrophic types of exercises when using a reasonably high numbers of repetitions and sets (Gotshalk *et al.*, 1997; Kramer *et al.*, 1990; and Kraemer and Häkkinen, 2002). Despite of the La/1RM trend to suggest the greatest condition to result in the greatest metabolic response, the data showed significant differences to support the 90% condition to lead to the greatest metabolic response and therefore to lead to the greatest increases in muscle hypertophy (Kraemer *et al.,* 2006). La change at 90% condition (9.5±2.33mmol/l) was observed to be the only significantly different ($P<0.05$) condition compared to 70% condition (7.7±1.15mmol/l). Also, La change was found to be significantly different between 70% and x/70% ($p<0.001$). Statistically significant differences in La change between the control and experiment conditions have greater significance when comparison is processed to individual highest concentrations instead of the group highest (figure 23 vs 24, respectively). The La change in 70% and in individualised x/70% conditions were 7.78±0.43 and 10.75±0.38mmol/l, respectively (average ± SEM). In addition, the trends seen in GH and La post values, and also in La and GH 1 repetition standardised levels support 90% and 100% conditions to produce the greatest metabolic responses. The significantly different La change in the 90% experiment condition compared to the control condition is in agreement with the hypothesis 3.

The post GH levels (figure 21) are the greatest at two of the highest conditions but no significant differences were observed between any of the conditions, such as in La post values. The standard error of mean was great in post GH concentration indicating high individual variance (SEM = 1.46-2.01). Also, the trend seen in GH response per 1 repetition supports the metabolic response determinations. Generally, the changes in GH level suggest rather the intensity alterations of the exercise than changes in the mode of contraction (Durand *et al.*, 2003). Therefore the observed GH trends are to support 90% condition to be the most intensive.

The previously presented metabolic response findings observed in the present study are similar to the observations presented by Kraemer *et al.* (2006). The results of the current study indicated the greatest metabolic response in the condition of 90% (determined by change in La). Therefore the present study had the greatest metabolic responses with load of 90% during ECC phase of a contraction, and 70% during CON phase. If expressing differently, the optimal ECC load was 1.2 times the CON resistance. In studies comparing individual ECC exercises to CON exercises, the ECC resistance is found to produce similar stress response compared to CON exercising once the ECC resistance is 1.2 times the resistance used in CON phase when the speed of the contraction is the same (Kraemer *et al.,* 2006).

Beside the absolute La, La change and La concentration per 1 repetition findings also the correlations observed in the present study provide some suggestions to DAER load selection on an individual level and a strong correlation between 1RM (/BM-ratio) and preferred load by La. The correlation between 1RM and La change emphasises the role of 1RM difference, and 1RM/BM-ratio difference in individuals to La production in DAER exercising. This novel finding could be probably elucidated by the property of elastic tissue functioning during DAER exercising. As the individuals with the greatest 1RM and 1RM/BM-ratios do not seem to produce too high levels of La at moderate DAER conditions, the elastic components of muscle tissue could be expected to function effectively in storing and releasing force during the contractions with low ECC resistance. Once the ECC resistance is increased in DAER exercising the role of elastic component diminishes and more voluntary force is required for ECC phase of the contraction. This increased demand of voluntary force during the ECC phase requires greater contractile component activity leading to greater metabolic response. Hence, it seems evident that as an individual gains strength (1RM increases) the elastic element capacity to generate force will develop more rapidly compared to the contractile component force generation development due training. This theory could be true based on the suggestions of Shadwick

(1990) who stated the degree of ground reaction forces applied on tendons to have influence on tendon growth and structure. Such development in elastic component would explain the relationship seen in figure 39. This is because the subjects with greater 1RM can be seen to be more trained and therefore their elastic elements are also more advanced (Shadwick, 1990). Therefore, each individual are required to "seek" for their elastic property threshold level in order to enable greatest possible metabolic response in "hypertrophic" type of DAER exercises. Such development in elastic component that is based on a theory presented by Shadwick (1990) would explain the relationship seen in figure 39. The "seeking" of resistance can be helped by the correlations provided in the present study (i.e. figure 39).

In addition, a moderate correlation coefficient improvement trend seen from earlier 1RM measurements to the latter 1RM measurements suggests the subjects' advancement in DAER exercising to result in a stronger correlation. This could be expected because the correlation processed between the 1RM prior the experiment and preferred ECC load by La was lower than the correlation processed between the 1RM results seen at later stages of the experiment when advancement in DAER exercising took place. Also, a comparison of figures 23 and 24 defines partly the importance of individually selected ECC load for DAER exercising. The level of significance is seen to increase between 70% and highest condition La concentration levels when ECC load is determined individually in DAER exercising compared to when group basis ECC load determination is used.

11.2. Kinetics

According to our knowledge there have been no studies to report any acute effects of DAER exercising to force generation. However, some of the studies have reported contraction type specific and also greater ISOM strength adaptations after ECC stimulus compared to CON exercising (Hortobagyi *et al.*, 1997). The present study did not report any increases in ISOM strength at any of the conditions. Though, significant differences were observed between pre and post values in all of the conditions of 70%, 80%, 90% and 100% in ISOM force ($P<0.001$) that can only indicate the accumulated fatigue at post measurement (figure 27).

The present study reported significantly greater ECC force output at all of the conditions compared to control condition of 70% in pre and post measurements. These significant differences in ECC force can be explained due to greater ECC resistances that were applied at different conditions. However, pre and post measurements of ECC force were not found to be significantly different at any of the conditions suggesting no ECC strength fatigue in any of the conditions in the present study.

As the CON force change was found similar in all the conditions the force could be more efficiently preserved during the greater resistance conditions (i.e. 90% and 100%). The energy preservation could be expected because of the similar rate of fatigue intake in all of the conditions despite of the number of diverse resistances used in different conditions. However, the number of repetitions needs to be considered, and even better, if total work of all ECC and CON phases was determined. The plyometric exercises is to favour the storage of elastic energy into series elastic component and as the series elastic and contractile components are shortening simultaneously the utilisation of this energy could be expected to be utilised in CON contraction. Therefore the less energy is needed for the contractions the more energy is stored in the elastic tissue (Enoka, 1994; and Walshe *et al.*, 1998). A clear evidence of energy preservation was not seen in the current study as the energy preservation determination would require a determination of work produced at each phase of the ECC and CON contraction and a determination of applied resistance relative to the energy used. The energy preservation during DAER exercising topic requires further studies.

The present study was preceded and followed by 1RM measurement test. The mean 1RM improved significantly ($P<0.05$) from pre (108.3±3.8kg) to post (110.0±3.8kg) measurement. This findings somewhat agrees the findings seen in strength in previous studies (Doan *et al.* ,2002; Hortobagyi *et al.,* 2001; and Brandenburg and Docherty, 2002). Though, this finding is not of importance as the present study did not have a control group for direct comparisons as the purpose of this study was not to observe the long term benefits from DAER exercising.

11. Muscle activity

The present study examines ECC, CON and ISOM EMG activity at pre, during, and post stage of different DAER conditions in 4 sets of 10 repetitions bench pressing. No significant differences was observed between traditional isoinertial exercising (70% condition, control condition) and any of the experiment conditions (80%, 90% and 100%) in post stage ISOM EMG activity. Neither any significant differences was seen between any of the conditions in ISOM EMG change activity from pre to post measurement.

ECC exercise association to contraction type specific adaptations suggests the ECC exercising often to be followed by ECC neuromuscular adaptations (Aagaard *et al.,*2000). The contraction type specific adaptation was observed in the present study as the only significant differences seen in EMG results took place during ECC actions. Significant difference was observed in ECC pre (±125ms) deltoid anterior mean EMG activity between 70% and 90% ($P<0.001$), and between 70% and 100% ($P<0.01$) conditions (figure 29). Interestingly, beside the EMG activity results seen in deltoid anterior ECC pre (±125ms) the level of La change is also the greatest at the corresponding conditions of 90% and 100% (figures 29 vs. 23). Also, similarly to the EMG activity of deltoid anterior ECC pre (±125ms) the responses seen in trends of post La concentration, GH post and GH change / repetition concentrations are peaking at the condition of 90% (figures 29, 19, 21 and 22, respectively). Despite of the similarities between the deltoid anterior EMG activity and La post levels of La, no further interpretations can be made based on the found relationship. This is because the La and GH levels are representations of whole body concentrations whereas EMG activity is localised deltoid anterior activity.

Significant differences was also observed between pre and post ECC pectoralis major mean EMG activity from pre to post measurement in 70%, 80% and 90% ($P<0.05$) but not in 100% condition. Pectoralis major was the only muscle with significant differences between pre and post conditions. This significant increase from pre to post measurement in EMG activity in 70%, 80% and 90% conditions could mean the pectoralis major to function as a major agonist muscle in this type of bench pressing exercise. An increase in EMG activation is a common response of muscle to maintain the required force level during fatiguing exercise (Enoka, 1994).

Antagonist activity is reported controversially to respond to ECC stimulus. There has been reported a trend towards smaller relative antagonist activation after exercising in the ECC quadriceps tests for a concentric training group (Seger and Thorstensson, 2005). This type of a trend was not directly seen in the present study results but the various DAER load levels were seen to generate evident changes into CON antagonist co-activation set (figure 36). This antagonist co-activation response seems to pair the lower DAER resistances with greater change in antagonist co-activation from pre to post measurement (from the start of an exercise to the end). Alternatively, the greater DAER resistances (such as 100%) seem to be associated with only minor changes in antagonist co-activation from pre to post measurement during the CON phase. The response seen in the antagonist co-activation in the present study could be due to a reduction in stretch-reflex component after fatiguing SSC contraction that also contributes to antagonist functioning. This is because a muscle spindle disfacilitation and activation of III and IV afferent nerve endings leading to reduced stretch reflex sensitivity, muscle stiffness and deterioration in force potentiation mechanism. (Komi, 2000).

11.4. Determinations encompassing DAER studies

In the stydy of Hortobagyi *et al.* (2001) ECC contractions were associated with greater strength development in sedentary females (age 20.9 yr). Comparatively, Godard *et al.* (1998) used 16 physically active males and 12 females, whereas Brandenburg and Docherty (2002), and Doan *et al.* (2002) used male subjects highly active in resistance exercising. Based on the previous observations of the gender, age or level of activation cannot be seen to contribute to the presented findings.

Godard *et al.* (1998) and Hortobagyi *et al.* (2001) used isokinetic dynamometer as a training instrument whereas the studies of Brandenburg and Docherty (2002), and Doan *et al.* (2002) used a free weight loading method in the exercising. Brandenburg and Docherty (2002) used a free weight method where an assistant person increased the weight by manipulating the weight discs on the bar during the repetitions. The specific time frame when the DAER was applied on the bar was not reported to be controlled in the study of Brandenburg and Docherty (2002). The method used in the study of Doan *et al.* (2002), according to our knowledge, is the only study so far to use a specified weight releaser technique for controlled and time frame based release of DAER. However, the study of Doan *et al.* (2002) was applied only to maximum resistance exercising.

Hence, based on the previous statements the present study is the only study that has researched DAER exercising with controlled time frame based release of additional ECC resistance and has also applied DAER exercising to subject group of physically active healthy males in “hypertrophic” protocol. In addition the present study is the only study that has researched the acute effects of various DAER resistances’ neuromuscular and metabolic responses. This is because the recent studies have still randomly estimated the quantities of loads used for the eccentric phase, as was done in the range of previous studies. Most of these studies either with “hypertrophic” or with muscle damage measurement protocols used ECC resistances in DAER exercising that were 40-50% greater compared to the CON resistance no matter of subjects’ training status, gender or age (Brandenburg and Docherty, 2002; Godard *et al.*, 1998; Hortobagyi *et al.*, 2001; and Johnson *et al.*, 1976). Compared to these studies the present study applied relatively low ECC resistances of 10-30% greater compared to CON resistance. Despite of the comparatively low ECC resistances used in the current study only 2/8 of the subjects could be seen to benefit of using ECC resistances beyond 100% for maximal La production even if the subject population used in the current study was consisted of healthy males who practice at the gym regularly.

11.5. Further studies

Additional, greater ECC loads should be studied for observation of metabolic responses per 1 repetition, post exercise metabolic levels, metabolic change levels and with concurrent EMG collection. Eventually, as the number of repetition reduces in conditions with great ECC resistance, the La concentration per 1 repetition level would be evidently expected to reduce. Also, a significant difference compared to other condition would be expected to be seen in metabolic pre to post change levels. In such a case, the certain optimal mean ECC resistance (for a subject group) in DAER exercising could be determined in purposed 4 sets of 10 repetitions "hypertrophic" protocol study where CON resistance is held constantly at 70%1RM. In such a DAER study even the subjects with great 1RM results could be studied for optimal ECC resistance. In the present study 6/8 of the subjects found their metabolic peaks at resistances less than 100%, based on the findings in La change (figures 39-42). The remaining 2/8 of the subjects found their peak La change with ECC resistance of 100%. Hence, theoretically these subjects could possess greater levels of change La at greater ECC resistances than 100%. Additional research needs to be conducted on individuals with high 1RM results and 1RM/BM-index for determination of optimal "hypertrophic" ECC DAER resistance. In addition, further studies are needed to determine the appropriate CON resistance in DAER exercising.

The findings of the present study need to be strengthened in future studies with greater size target populations for improvements in statistical power in various measures. For instance, despite of the clear La response results the present study was incapable to confirm the metabolic responses in GH levels. Also some of the future studies could include testosterone concentration determinations into the analysis of optimal DAER loadings in "hypertophic" exercising.

In addition to greater DAER resistances the research could be extended to lower loads exercising, or at least using lower resistances in testing purpose for research of motor unit selective activation. This is because lower force levels mean spike amplitude has been detected to be higher in ECC than in CON actions, which might indicate selective activation of fast motor units to be seen after continuous participation to DAER exercising (Linnamo *et al.*, 2003).

Before any studies are done to determine the DAER exercising relation to CON load used, energy consumption, motor unit activation models, or to age factor the research should reach better comprehension on optimal loads used during explosive and maximal strength demanding protocols. Especially explosive training can be seen to benefit of additional ECC stimulus because of the highest force during SSC is detected in movements with fast contraction velocity, such as in jumping and hopping. From this can be interpreted that series elastic component is storing energy most effectively during fast ECC velocity of a movement for later usage in immediately following CON phase (Enoka, 1994).

11.6. Conclusion

The found correlation provide suggestions to DAER load selection on an individual level whereas to show the strong correlation between 1RM (/BM-ratio) and preferred load by La. The correlation between 1RM and La change emphasises the role of 1RM to the load used, and the importance of 1RM (/BM-ratio) difference to La production in DAER exercising. This novel finding could be probably elucidated by the property of elastic tissue functioning during DAER exercising.

One of the major findings in the present study is the significant differences in the La change between the 70% and 90% conditions ($P < 0.05$). Also, the comparison to show the significant difference between the individual control condition La change and the individual highest La change ($P < 0.001$) can be observed as one of the primer findings. The latter finding also emphasises the importance of individualised load selection for DAER exercises. In addition, the similar trends to La responses seen in GH concentrations support the major conclusions done in this experiment. Therefore the present study had the greatest metabolic responses with loads of 90% during ECC phase of a contraction, and 70% during CON phase. The optimal ECC load for the subject group used in the present study is 20% greater compared to CON resistance in the applied “hypertrophic” DAER exercising.The present study provides new suggestions for the determination of resistance used in DAER exercises.

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APPENDIX

13.1. Images

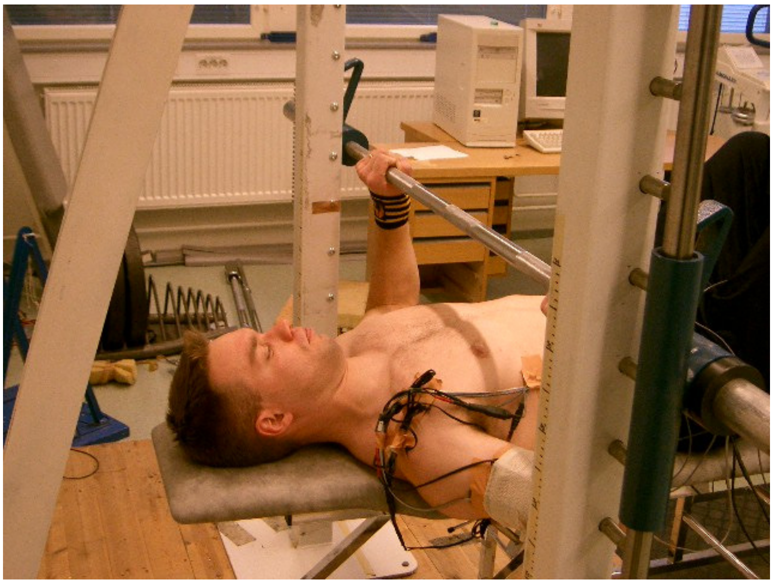

FIGURE 40. Bench-pressing set up used in the dynamic and ISOM measurements.

FIGURE 41. Weight-releaser used in the experiment conditions.

13.2. Subject information and written consent form

Tutkimuksen nimi : ”Erisuuruisten eksentristen kuormitusten vaikutus eksentris-konsentrisessa suorituksessa ja niiden vaikutus neuromuskulaariseen, kasvuhormoni ja laktaatti muuttujiin maksimaalisissa, räjähtävissä ja hypertropisissa toistoissa”

TIEDOTE TUTKITTAVILLE JA SUOSTUMUS TUTKIMUKSEEN OSALLISTUMISESTA

Tutkijoiden yhteystiedot

Tutkimuksen vastuullinen johtaja
Nimi: Prof. Keijo Häkkinen

Tutkija:
Nimi, arvo, opiskelupaikka: Timo Ojasto, MSc-opiskelija, Liikuntabiologian laitos, JYO
Osoite: Taitoniekantie 9 A 210, 40740 Jyväskylä
p. 040-7651751
e. titaojas@cc.jyu.fi

Tutkimuksen taustatiedot

Tutkimus suoritetaan Jyväskylän yliopiston liikuntabiologianlaitoksella, VTE-laboratoriossa (Rautpohjankatu 8, Viveca). Professori Keijo Häkkisen johtama tutkimus: ” Erisururuisten eksentristen kuormitusten vaikutus eksentris-konsentrisessa suorituksessa ja niiden vaikutus neuromuskulaariseen, kasvuhormoni ja laktaatti muuttujiin maksimaalisissa, räjähtävissä ja hypertropisissa toistoissa” on yksittäinen tutkimus jonka tarkoitus yleisesti on selvittää erisuuruisten eksentristen kuormitusten merkitys räjähtävyyttä, maksimaalista voimaa ja lihaksen kasvua kehittävissä eksentris-konsetrisissa lihasaktivaatioissa.

Tutkimus suoritetaan aikavälillä 18.9.-30.11.2006.

Tutkimusaineiston säilyttäminen

ATK:lla oleva tutkimusaineisto tullaan arkistoimaan ilman henkilöiden tunnistetietoja valmennus ja testauskäyttötarkoituksiin vastaavalle tutkijalle. Vastaava tutkija vastaa tutkimusaineiston turvallisesta säilyttämisestä. Manuaalista aineistoa säilytetään lukitussa tilassa tutkimuksen aikana ja tullaan hävittämään materiaalin analysoinnin jälkeen.Tutkimustuloksia käsitellään luottamuksellisesti eikä tutkimushenkilöiden nimiä julkaista.

Tutkimuksen tarkoitus, tavoite ja merkitys

Kuvaus tutkimuksen sisällöstä ja mikä on tutkimuksen tarkoitus ja tavoite?
Tutkimus koostuu kolmesta mittausvaiheesta: maksimaalinen-, hypertropinen- ja räjähtävävoima. ”The effect of different eccentric load levels in eccentric-concentric loading contractions on acute neuromuscular, growth hormone and blood lactate responses during maximal strength, explosive strength and hypertrophic protocols” tarkoituksena on selvittää hermolihasjärjestelmän sekä hormonijärjestelmän toimintaa erisuuruisilla eksentrisillä penkkipunnerruskuormituksilla räjähtävissä, maksimaalisissa, sekä lihasta kasvattavissa suorituksissa (hypertropinen) tehokkaimman eksentris-konsentrisen kuormittamisen löytämiseksi. Tavoitteena on löytää optimaaliset eksentris-konsetriset kuorimitukset kaikissa kolmessa vaiheessa, joilla saavutetaan suurimmat teho, lihasaktivaatio, hormonaaliset- sekä laktaattiarvot.

Tutkija tekee mittaustuloksista yhteenvedot, tieteellisen tutkimusraportin, joita käytetään hyväksi perustietona sellaisenaan sekä kuntoilun ja kilpaurheilun kehittämisessä. Lisäksi tuloksia voidaan esittää ammatillisissa koulutustilaisuuksissa.

Menettelyt, joiden kohteeksi tutkittavat joutuvat

Tutkimukseen sisältyy omatoiminen harjoitusjakso joka on määritelty yleiset ohjeet-monisteessa. Tutkittavilta tullaan mittauksen ensimmäisessä kolmesta vaiheesta testaamaan maksimaalisia penkkipunnerrus suorituksia eri eksentris-konsetrisilla kuorimilla. Ensimmäisenvaiheen mittauksissa tullaan käyttämään pintaelektrodeja lihasaktivaation mittaamiseksi sekä kyynärkulmamittaukseen goniometrilaitteistoa. Kiihtyvyysmittaus tapahtuu penkkiin kiinnitetyllä ultraäänilaitteistolla.

Mittausten toisessa vaiheessa tullaan mittaamaan maksimaalista tehoa ultraäänellä sekä lihasaktivaatiota pintaelektrodeilla.

Kolmannessa vaiheessa tullaan ottamaan laktaatti sekä hormoninäyte mittaussession aluksi ja lopuksi. Lisäksi mitataan lihasaktivaatiota pintaelektrodeilla ja maksimaalista tehoa ultraäänellä.

EMG-elektrodien laitossa ihosta puhdistetaan ihokarvat ja kuollut ihosolukko partakoneella ja hiekkapaperilla, mikä saattaa altistaa elimistön tulehduksille. Infektiovaaraa pienennetään käyttämällä kertakäyttövälineitä ja puhdistusaineita. EMG- pisteet voidaan merkitä tarvittaessa hyvin pienellä (noin 1 mm) mustetatuointipisteellä, joka pysyy näkyvissä ihossa pitkän aikaa.

Hormoninäytteistä analysoidaan kasvuhormonitasoa eri kuormituksilla. Veren laktaattiarvoa seurataan myös vastaavasti.

Tutkimuksen hyödyt ja haitat tutkittaville

Mitä tutkittavat hyötyvät osallistumisestaan tutkimukseen.

Tutkittava tulee saamaan tutkimuksesta tietouteensa yksilökohtaista sekä ryhmään perustuvaa tietoa eri kuormitusten soveltuvuudesta. Kuormitusten soveltuvuutta voidaan arvioida välittömästi tutkimuksen aikana yksilökohtaisista mittaustuloksista tai ryhmään perustuvasti analysointiprosessien jälkeen. Lisäksi mittauskerroista koostuu tehokas vaihtelevalla kuormituksella tehty harjoitusjakso tutkittavalle.

Suurimmat hyödyt:

+Optimaaliset kuormitukset:

-1.maksimivoima, 2.räjähtävät, 3.hypertopinen

-analysointi: dynaaminen ja staattinen voima, nopeus, teho, hormoni vasteet, EMG vasteet

+Voima/Nivelkulma analysointi (suullinen/graafinen analyysi)

+Harjoitusvaikutus ja sen analysointi

+Sovellukset harjoitteluun

Tutkimukseen liittyvät riskit ja mahdolliset haitat.

Kuten liikuntaan ja urheiluun yleensä, niin myös tähän tutkimukseen liittyy loukkaantumisriskejä mittauksissa tapahtuvien ponnistelujen vuoksi. Maksimaalisessa lihassupistuksessa ja kuormituksessa saattaa tuki- ja liikuntaelimistöön tulla vaurioita tai vammoja esimerkiksi lihasrevähtymä tms. Kuormituskokeissa kuten yleensäkin kovassa liikunnassa on aina olemassa sydämen, verenkiertoelimistön ja/tai hengityselimistön ylikuormittumisen vaara, jolloin pahimmassa tapauksessa voi seurata sydämen hapenpuute, rytmihäiriö tai muu kohtalokas häiriö normaalissa toiminnassa. Tutkimuksen tarkoituksena on kuormittaa elimistöä aika ajoin varsin voimakkaasti, minkä seurauksena kädet ja rinta saattavat kipeytyä ja olla arkoina useita päiviä. Mittauslaitteet saattavat hangata aiheuttaen pieniä hiertymiä tai muita hankaluuksia. EMG-elektrodien laitossa ihosta puhdistetaan ihokarvat ja kuollut ihosolukko partakoneella ja hiekkapaperilla, mikä saattaa altistaa elimistön tulehduksille. Infektiovaaraa pienennetään käyttämällä kertakäyttövälineitä ja puhdistusaineita. EMG- pisteet voidaan merkitä tarvittaessa hyvin pienellä (noin 1 mm) mustetatuointipisteellä, joka pysyy näkyvissä ihossa pitkän aikaa. Kuten normaalissa terveydenhoitoon liittyvissä verikokeiden otossakin, infektiovaara on olemassa myös tutkimuksessa suoritettavissa verikokeissa.

Tutkimuksessa käytetään myös suuria kuormia jotka voivat sisältää riskejä kuten normaalikin voimaharjoittelu. Tässä tutkimuksessa ollaan pyritty rajoittamaan normaaliin voimaharjoitteluun liittyviä riskejä käyttämällä laitteistoja joissa riskien määrä on minimoitu. Näistä esimerkkeinä isometriset eli staattiset voimamittaukset, dynaamisten mittausten suorittaminen smith-laitteessa ja varmistaja-henkilön läsnäolo. Näin ollen riskien osuus tutkimuksessa jää varsin pieneksi.

Tutkimuksissa käytettävä henkilökunta on asiansa osaavia ja koulutettuja tehtävän edellyttämällä tavalla.

Onnettumuuden tai loukkaantumisen sattuessa tutkimusyksikössä on tarpeen vaatima ensiapu annettavissa.

Näytteidenotosta (verikokeet) aiheutuvat hankaluudet voivat sisältää mm. infektoitumista, mustelmia iholla ja lievää turvotusta.

Miten ja mihin tutkimustuloksia aiotaan käyttää

Tutkimustuloksia aiotaan käyttää opinnäytetyön materiaalina mahdollisessa kansainvälisessä tai kansallisessa julkaisussa sekä materiaalina kongressi- ja seminaariesityksissä. Materiaalia voidaan käyttää myös opetus tai perustietona sellaisenaan, sekä kuntoilun ja kilpaurheilun kehittämisessä. Lisäksi tuloksia voidaan esittää ammatillisissa koulutustilaisuuksissa.

Tutkittavien oikeudet

Osallistuminen tutkimukseen on täysin vapaaehtoista. Tutkittavilla on tutkimuksen aikana oikeus kieltäytyä mittauksista ja keskeyttää testit ilman, että siitä aiheutuu mitään seuraamuksia. Tutkimuksen järjestelyt ja tulosten raportointi ovat luottamuksellisia. Tutkimuksesta saatavat tiedot tulevat ainoastaan tutkittavan ja tutkijaryhmän käyttöön ja tulokset julkaistaan tutkimusraporteissa siten, ettei yksittäistä tutkittavaa voi tunnistaa. Tutkittavilla on oikeus saada lisätietoa tutkimuksesta tutkijaryhmän jäseniltä missä vaiheessa tahansa.

Vakuutukset

Tutkittavat on vakuutettu tutkimuksen ajan ulkoisen syyn aiheuttamien tapaturmien, vahinkojen ja vammojen varalta. Tapaturmavakuutus on voimassa mittauksissa. Vakuutus-yhtiöt eivät kuitenkaan korvaa äkillisen ponnistuksen aiheuttamaa lihas- tai jännerevähdystä, ellei siihen liity ulkoista syytä. Tapaturmien ja sairastapausten välittömään ensiapuun mittauksissa on varauduttu tutkimusyksikössä. Laboratoriossa on ensiapuvälineet ja varusteet, joiden käyttöön henkilökunta on perehtynyt. Tutkittavalla olisi hyvä olla oma henkilökohtainen tapaturma/sairaus- ja henkivakuutus, koska tutkimusprojekteja varten vakuutusyhtiöt eivät myönnä täysin kattavaa vakuutusturvaa esim. sairauskohtauksien varalta.

Tutkittavan suostumus tutkimukseen osallistumisesta

Olen perehtynyt tämän tutkimuksen tarkoitukseen ja sisältöön, tutkittaville aiheutuviin mahdollisiin haittoihin sekä tutkittavien oikeuksiin ja vakuutusturvaan. Suostun osallistumaan mittauksiin ja toimenpiteisiin annettujen ohjeiden mukaisesti. En osallistu mittauksiin flunssaisena, kuumeisena, toipilaana tai muuten huonovointisena. Voin halutessani peruuttaa tai keskeyttää osallistumiseni tai kieltäytyä mittauksista missä vaiheessa tahansa. Tutkimustuloksiani saa käyttää tieteelliseen raportointiin (esim. julkaisuihin) sellaisessa muodossa, jossa yksittäistä tutkittavaa ei voi tunnistaa.

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Päiväys Tutkittavan allekirjoitus

____

Päiväys Tutkijan allekirjoitus

13.3. Healthy questionnaire

Terveyskysely

Nimi:

1. Onko terveytenne yleisesti ottaen…

1	erinomainen
2	varsin hyvä
3	hyvä
4	tyydyttävä
5	huono

2. Yläraajojenne kunto

1	erinomainen
2	varsin hyvä
3	hyvä
4	tyydyttävä
5	huono

3. Rajoittaako yläraajojenne kunto nykyisin suoriutumistanne erilaisista tehtävistä? Jos rajoittaa niin kuinka paljon (1=kyllä rajoittaa, 2=hiukan, 3=ei rajoita)

1	Raajojen taivuttaminen…………...1……….2……..3
2	Esineiden nostelu…….……….…..1……….2……..3
3	Pitkäkestoinen kevyt ponnistelu….1……….2……..3
4	Intensiivinen ponnistelu…..............1……….2……..3

-Jos yläraajoissanne on ollut erinäisiä toimintaa rajoittavia hankaluuksia kuten loukkaantumisia tai leikkaustoimenpiteitä, määritelkää mitä ne ovat ja kuinka olette toipunut niistä.

Määrittelyt: ____

____

4. Alaraajojenne kunto

1	erinomainen
2	varsin hyvä
3	hyvä
4	tyydyttävä

5 huono

5. Rajoittaako alaraajojenne kunto nykyisin suoriutumistanne erilaisista tehtävistä? Jos rajoittaa niin kuinka paljon (1=kyllä rajoittaa, 2=hiukan, 3=ei rajoita)

1 Raajojen taivuttaminen…………...1……….2……..3
2 Esineiden nostelu…….………..…..1……….2……..3
3 Pitkäkestoinen kevyt ponnistelu….1……….2……..3
4 Intensiivinen ponnistelu…..............1……….2……..3
5

-Jos alaraajoissanne on ollut erinäisiä toimintaa rajoittavia hankaluuksia kuten loukkaantumisia tai leikkaustoimenpiteitä, määritelkää mitä ne ovat ja kuinka olette toipunut niistä.

Määrittelyt: ______________________________

____

6. Vartalonne kunto

1 erinomainen
2 varsin hyvä
3 hyvä
4 tyydyttävä
5 huono

7. Rajoittaako vartalonne kunto nykyisin suoriutumistanne erilaisista tehtävistä? Jos rajoittaa niin kuinka paljon (1=kyllä rajoittaa, 2=hiukan, 3=ei rajoita)

1 Raajojen taivuttaminen…………...1……….2……..3
2 Esineiden nostelu…….………..…..1……….2……..3
3 Pitkäkestoinen kevyt ponnistelu….1……….2……..3
4 Intensiivinen ponnistelu…..............1……….2……..3
5

-Jos vartalossanne on ollut erinäisiä toimintaa rajoittavia hankaluuksia kuten loukkaantumisia tai leikkaustoimenpiteitä, määrittele mitä ne ovat ja kuinka olette toipunut niistä.

Määrittelyt: ______________________________

____

8. Oletteko tällä hetkellä altistunut jollekin taudille tai sairaudelle? Jos olette niin määritelkää tauti:

Määrittelyt: ____

____

8. Kärsittekö sydämen toimintaan liittyvistä sairauksista? Jos kärsitte niin määritelkää sairaus:

Määrittelyt: ____

____

9. Kärsittekö jostain pysyvästä sairaudesta? Jos kärsitte niin määritelkää sairaus:

Määrittelyt: ____

____

10. Onko teillä olemassa jokin voimassa oleva lääkitys? Jos on niin määritelkää lääkitys:

Määrittelyt: ____

____

11. Haluatteko kertoa jotain muuta terveyteenne liittyvää minkä katsotte olevan aiheellista kertoa ennen mittausten alkua?

Määrittelyt: ____

____