Masteroppgave

Effects of smokless tobacco on recovery time following a leg-extension exercise

Vegard Fånes Aaring

Nord-Trøndelag University College – Department of Physical Education

Juni 2010

HØGSKOLEN I NORD-TRØNDELAG

SAMTYKKE TIL HØGSKOLENS BRUK AV MASTER-/BACHELOR-/KANDIDAT- OG PROSJEKTOPPGAVER

Forfatter(e): _____

_____

Tittel: _____

_____

Studieprogram: _____

☐ **Vi/jeg samtykker i at oppgaven gjøres tilgjengelig på høgskolens bibliotek**

☐ **Vi/jeg samtykker i at oppgaven kan publiseres elektronisk**

☐ **Vår/min oppgave inneholder taushetsbelagte opplysninger og må derfor ikke gjøres tilgjengelig for andre**

Kan frigis fra: _____

Dato:

_____ _____

underskrift **underskrift**

_____ _____

underskrift **underskrift**

_____ _____

underskrift **underskrift**

Contents

ABSTRACT

Purpose: The aim of this study was to investigate the effect of smokeless tobacco (ST) upon recovery time. Specifically, we wanted to investigate the effect of ST in the time to recover peak power (PP), peak force (PF) and maximal voluntary isometric contraction (MVIC) after a fatiguing leg-extension exercise. It was hypothesized that use of ST would lead to delayed time of recovery in muscular force and power following a fatiguing leg-extension exercise. It was also hypothesized that PF and PP would be lower, and time-to PF (TtPF) and PP (TtPP) would be higher, with use of ST than without. **Method:** Six male ST users playing football at the third level in Norway volunteered to participate in the study. To analyze the effects of smokeless tobacco on recovery time, the six male ST users were initially tested seated in a plate loaded leg extension apparatus: i) 1RM; ii) maximal voluntary contraction at 50% of 1RM (MVC_{50}); iii) peak power (PP_{50}) and peak force (PF_{50}) in the MVC_{50}; iv) TtPP ($TtTP_{50}$) TtPF ($TtPF_{50}$) in the MVC_{50} and; v) maximal voluntary isometric contraction (MVIC). After these baseline tests the subjects were randomly tested according to an AB design. In either conditions, A and B, the test started with a fatigue stimulation bout of the muscles involved in the leg extension exercise, until exhaustion. After ending the fatigue stimulation protocol, the subjects remained seated in the leg extension apparatus and, every other minute; they performed one repetition with a load corresponding to MVC_{50}. Force and power variables were registered during these repetitions, and when the subjects reached their baseline values, they were considered to be recovered from the fatigue stimulation. These tests were conducted within the first 30 minutes of the recovery period. **Results:** No significant differences were revealed upon any of the scores obtained in baseline and during the recovery tests, with or without ST in $PP_{50,}$ mean PP_{50} and $TtPP_{50}$. Significant effect of time was found in the PP_{50} during the recovery test, but no effects of ST or interaction between time and ST during the PP_{50} recovery test were found. No significant differences were revealed obtained from the baseline scores, with or without ST in PF_{50} during the recovery tests, but the subjects mean PF_{50} proved to be significant higher with ST than without during the recovery test, and the $TtPF_{50}$ was significantly higher than the scores obtained in baseline. The time to recover PF_{50} during the recovery test, proved significant increased with use of ST, compared to without use of ST. MVIC at baseline proved to be significantly higher than the MVIC scores during the recovery test without ST.

INTRODUCTION

The aim of this study was to investigate the effect of smokeless tobacco (ST) upon recovery time. Specifically, we wanted to investigate the effect of ST in the time to recover peak power (PP), peak force (PF) and maximal voluntary isometric contraction (MVIC) after a fatiguing leg-extension exercise.

In Scandinavia the use of ST is extensive, and has increased during the last decades. This is particularly reflected among youths (Nordgren & Ramstrøm, 1990; Pershagen 1996). A Norwegian survey shows that approximately 10% of Norwegian youths daily uses ST, and almost 20% have tried it once or more (SIRUS, 2007). Several studies report that ST seems to be more extensive among athletes than none-athletes (Davis, 1997; Melnick, 1997; Escher, 1998). Today there is a number of studies surrounding ST. Mostly they concerns health and the risk of disease (Pershagen, 1996; Benowitz, 1998; Asplund, 2003), and the acute physical performance (Schroeder & Chen, 1985; Ksir et al., 1986; Edwards et al., 1987; Glover et al., 1989; Guggenheimer, 1991; Landers et al., 1992; Van Duser & Raven, 1992; Escher, 1998; Edquist, 2004; Karlsen, 2004). Rather few studies seem to deal with fatigue recovery.

Smokeless tobacco originates from the tobacco plant Nicotiana. The tobacco is dried and treated so the finished product for sale appears to be a damp dark mass (Strømme, 2001). Processed tobacco contains as much as 2000 chemical compounds, and a numerous additives such as salt, ammonia, spices and condiments (Pershagen, 1996). Alkaline buffer agents are added to the ST, for example sodium carbonate, potassium carbonate and potassium-bicarbonate. This results in that ST is a fairly strong alkaline with a pH value between 8.0 and 9.5 (Pershagen, 1996). Nicotine is a liquid alkaloid with the chemical formula $C_{10}H_{14}N_2$. Such drugs have proved a significant effect on the organism, and they are known from the pharmaceutical industry, for example in morphine (Edquist, 2004). Smokeless tobacco can have both a stimulating and a calming effect on the nervous system, and it is suggested that the alkaloids exerts its effect by binding to receptors in the brain (Edquist, 2004). The receptors lead to an increased release of signaling substances which triggers other reactions in the organism, including the endocrine process resulting in an increase of dopamine. Some authors claim the nicotine to be at greatest extent to the nicotinic receptors in sympathetic ganglia and the adrenal medulla, which leads to increased secretion of epinephrine and norepinephrine (Cryer et al., 1976; Guggenheimer, 1991; Lumbardo, 1998; Edquist, 2004).

In the present study, muscle fatigue is one of the main variables. Muscle fatigue is defined by Vøllestad (1997, p.222); 'as a reduction in the maximal strength generating capacity caused by muscle contraction'. It is common to divide fatigue into central and peripheral fatigue. Central fatigue is often defined as; 'a decline caused by a reduction in the firing frequency of the motoneurons' (Åstrand et al. 2005, p.457). Peripheral fatigue is by Åstrand et al. (2003, p.457) defined as; 'a force or power deficit that occurs despite optimal activation of the muscle fibers by their motoneurons'.

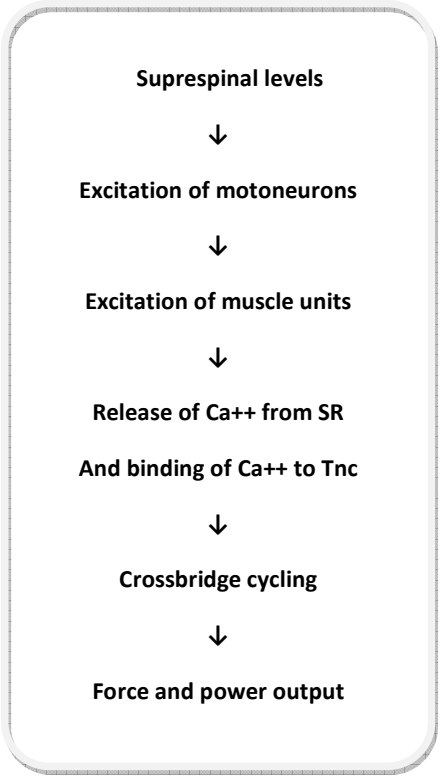

Figure 1: The chain of command during voluntary activation of a skeletal muscle (Åstrand et al. 2003, p.455).

During sustained muscle actions, central and peripheral fatigue has proved to develop during maximal, as well as submaximal voluntary efforts (Bigeland-Ritchie et al., 1983; Löscher et al., 1996). At intermittent muscle actions during maximal effort, both central en peripheral fatigue has shown to develop (Taylor et al., 2000), whereas at submaximal effort or when there is sufficient rest between each action, fatigue has shown mainly to be due peripheral mechanisms (Bigeland-Ritchie et al., 1986).The impairment of performance resulting from muscle fatigue differs according to physical fitness, type of contraction involved, the duration and intensity of the exercise and muscle groups tested (Bigeland et al., 1986).

A voluntary force generation results from a sequence of events. Åstrand et al., (2003, p.455) points to that fatigue might be caused by deficient function in the chain of command during a voluntary activation of skeletal muscles, at any of these steps (Fig. 1). The first thing pointed out in the chain, concerns all central factors which influence the activation of the motoneurons, motivational factors or the sensory information (Vøllestad, 1997).

It has been suggested that central fatigue might be due to suboptimal facilitation from motor cortex (Taylor et al., 2000), decreased facilitation from the muscles spindles, increased inhibition from group III and IV afferents (Åstrand et al., 2003, p.462-463) and a decreased sensitization of the motoneurons (Kernell, 1969).

In the next step these central factors leads to generation of action potentials (AP) at the sarcolemma. During exercise the balance of Na^+/K^+ ions over the sarcolemma and t-tubule membrane changes, which might impair the propagation of the AP (Vøllestad, 1997). A consequence of this is that the amount of Ca^{2+} release from sarcoplasmatic reticulum (SR) into the cytosol decreases, which in next step might influence the binding of Ca^{2+} to the troponin C. A result of this is reduced bindings between actin and myosin, which leads to decreased force per cross bridge, and in turn lower force and power.

The cross-bridge cycling during maintenance of force is highly dependent upon sufficient supply of ATP through aerobic/anaerobic pathways. Metabolic factors such as lactate, hydrogen ion (H^+) and inorganic phosphate (P_i) in association to peripheral fatigue has been investigated for ages. The accumulation of lactic acid in the muscle has historically been suggested to be the major cause of muscle fatigue. However, the raised levels of H^+-ions which results in reduced pH, has proved to be of a much greater impact (Westerblad & Allen, 2002).

Fatigue recovery is considered to be how the organism regains its metabolic balance and force production back to resting levels (Allen et al. 2008). In the present study recovery is considered to start immediately after the fatigue stimulation period. This means that the fatigue-induced impairment in muscle function does not necessarily have to improve during the initial part of the recovery period. In fact the opposite is observed. For instance Westerblad & Allen (1986) demonstrated that fast-twitch frog muscle fibers showed a marked force decrease after the end of fatiguing stimulation. This has been named the post contractile depression (PCD).

There might be different time courses of recovery and restoration of force production after a fatigue induced stimulation. In addition recovery of force after fatigue induced by repeated short tetani is proved completed within 30 min tested at high frequencies (close to maximal), whereas the level of force at low frequencies stimulation may be markedly depressed for hours (Westerblad & Allen, 1986).

Edwards et al. (1977) and Hill et al. (2001) points to that following severe or prolonged exercise, the force deficit might be due to changes in muscle function that may last for hours. The deficit does not seem to be due to reduced levels of ATP or CrP, or the increase of

metabolites, because these returns close to resting levels within 15 to 60 min (Edwards et al. 1977; Tupling et al., 2000; Hill et al., 2001).

Fatigue concerns changes in isometric force, maximal shortening velocity and the curvature of the force-velocity relationship. The above mentioned factors have different underlying mechanism, which all affects the power output (Allen et al., 2008). A transient increase of inorganic adenosine phosphate (ADP_i) appears to play a certain role at the decrease in maximal shortening velocity induced by fatigue. Inorganic phosphates or H^+ has however proved to have little impact on this parameter. In addition P_i seems to decrease the myofibrillar capacity to generate force and impairs SR Ca^{+2} handling, which is earlier mentioned as one of the major causes of fatigue (Westerbald & Allen, 2002).

Several studies have shown that ST increases heart rate and systolic blood pressure, both at rest and during exercise (Schroeder & Chen, 1985; Ksir et al., 1986; Edwards et al., 1987; Glover et al.,1989; Landers et al., 1992; Karlsen, 2004). Heart rate (HR) might increase as much as 15 beats per min (Guggenheimer, 1991; Edquist, 2004). This results from vasoconstriction, and decreases the ability to deliver oxygen (O_2) to the muscle fibers as well as their utilization of O_2 (Guggenheimer, 1991; Edquist, 2004; Åstrand et al., 2005, p.449). The raised level of carbon monoxide during use of smokeless tobacco is also proved to reduce the O_2 transport. This is due to the hydrogen cyanide which inhibits the enzyme systems necessary for the oxidative metabolism (Åstrand et al. 2002, p.449). Van Duser and Raven (1992) demonstrated in ST users a significant increase in lactic acid concentration and lowered stroke volume during exercise at 60% and 85% of VO_{2max} and at rest. A study by Williams & Wilkins (1998) concluded that ST use had no effect on reaction time, but ST use may have detrimentally influenced the maximum voluntary force and maximum rate of force generation (Escher et al., 1998). Lester et al. (1988) suggested that ST use causes a delay in the nervous transmission across the neuromuscular junction. A urine output is also shown decreased with antidiuretic hormone levels, which increases satiety and in next step helps to decrease weight (Lombardo, 1986). Åstrand et al. (2002, p.448-449) reports associations between tobacco use and delayed tissue healing, and Silverstein (1992) observed a slower healing in wounds resulting from trauma, disease or surgical procedures.

These findings indicate that ST might increase the time of fatigue recovery, and it was hypothesized that use of ST would lead to delayed time of recovery in muscular force and

power following a fatiguing leg-extension exercise. It was also hypothesized that PF and PP would be lower, and time-to PF and PP would be higher, with use of ST than without.

MATERIALS AND METHODS

Experimental Approach to the Problem

To analyze the effects of smokeless tobacco on recovery time, six male ST users playing football were initially tested seated in a plate loaded leg extension apparatus (Fig.3): i) 1RM; ii) maximal voluntary contraction at 50% of 1RM (MVC_{50}); iii) peak power (PP_{50}) and peak force (PF_{50}) in the MVC_{50}; iv) TtPP ($TtTP_{50}$) TtPF ($TtPF_{50}$) in the MVC_{50}; and v) maximal voluntary isometric contraction (MVIC).). After these baseline tests the subjects were randomly tested according to an AB design. In either conditions, A and B, the test started with a fatigue stimulation bout of the main muscles involved in the leg extension exercise, i.e. QF, until exhaustion. The exercise was accomplished seated in the same leg extension apparatus as used in the baseline examination. After ending the fatigue stimulation protocol, the subjects remained seated in the leg extension apparatus and, every other minute; they performed one repetition with a load corresponding to MVC_{50}. Force and power variables were registered during these repetitions, and when the subjects reached their baseline values, they were considered to be recovered from the fatigue stimulation. These tests were conducted within the first 30 minutes of the recovery period. Under condition A the subjects used ST during the recovery period after the fatigue stimulation bouts, whereas in B they abstained from ST twelve hours before testing and during the recovery period.

Subjects

Six male ST users playing football at the third level in Norway volunteered to participate in the study, which was approved by the Ethics Committee, Trondheim, Norway. Approval was also obtained from the Norwegian Data Inspectorate.

The subjects met the following criteria: i) 18-25 years old; ii) involved in regular football 1.5 hour per day at least 4 times a week in the last year; iii) they were in good health; iv) they all had experience with strength training and, in particular, they were experienced in the leg extension exercise applied in this study. The subjects were given oral and written information (appendix 1) about the purpose of the study, procedures, and possible risks of participating. Thereafter the subjects gave their written informed consent to participate in the study. The characteristics of the subjects' are shown in (Tab.1).

Table 1: Anthropometrics and strength characteristics of the subjects at baseline (N=6)

Subject	Height (cm)	Weight (kg)	BMI	[1]1RM dynamic (kg)	[2]MVIC (N)
1	192.1	80.3	21.7	176.3	1343.0
2	180.3	74.2	22.8	181.3	1503.0
3	176.2	68.2	22.0	148.3	1527.5
4	176.0	68.0	22.0	148.3	1363.0
5	190.1	81.0	22.4	159.3	963.8
6	176.2	75.1	24.2	176.3	1510.0
Mean:	**181.8**	**74.5**	**22.5**	**165.0**	**1368.4**

[1]The subjects 1RM in the seated leg extension exercise. [2]The subjects maximal voluntary isometric contraction in the seated leg extension exercise.

Procedure

Pilot study

Before the investigation started, a pilot study with sports science students from The Nord-Troendelag University College was conducted. We first determined each sport science students' 1RM baseline value in the seated leg extension exercise.

Afterwards different loads for the fatigue stimulation protocol were examined, as well as which load to use in the MVC during the recovery period. It was found that a load corresponding to 60% of 1RM in the fatigue stimulation protocol in combination with MVC at 50% of 1RM in the recovery period, brought the subjects back to baseline levels within 12 to 25 min. Heavier loads in the fatigue stimulation protocol, and lower loads in the MVC during the recovery period, revealed that the subjects recovered too fast (6-12 min).

Main study

The subjects accomplished two days of training with the leg extension exercise applied in this study, in order to get familiarized with the testing equipment and the experimental protocol. This training consisted of 3x15 repetitions at a light weight.

After this familiarization procedure, the subjects returned to the laboratory after 3 to 5 days in order to perform baseline examinations. The baseline examinations started with a 10 min warm up in a cycle ergo meter at 60% of their reported maximal HR.

Thereafter 1RM in the seated leg extension apparatus was determined as described by Kraemer (1995, p.121), in order to calculate the loads to use in the fatigue stimulation protocol (60% 1RM) as well as the MVC_{50} in the recovery period.

After a 10 min break, the subjects MVC_{50} were determined. The highest measured PP and PF of the subjects' two trials represented the PP_{50} and PF_{50} baseline levels in the leg extension exercise at a MVC_{50}.

The subjects' MVIC in the seated leg -extension apparatus was the last baseline test determined. The subjects performed a maximal isometric effort, and kept the contraction for three seconds. The PF during the MVIC of the subjects' two trials represented their MVIC at baseline.

During the next six days, the subjects revisited the laboratory two times, and was randomly assigned to accomplish A; one day of testing using ST during the test, and B; one day of testing abstaining from ST at minimum twelve hours before testing and during the test. The half-life of nicotine is ~2 h (Gritz et al., 1981; Benowitz, 1988). Twelve hours, or six degradation half-lives, would theoretically bring the nicotine level to near zero (Williams & Wilkins, 1998). During condition B the subjects consumed one portion (1 gram) ST from the time they arrived the laboratory, until the test was ended.

The warm up procedure was the same as described for the baseline tests. Thereafter the fatigue stimulation protocol seated in the leg extension apparatus at 60% of the subjects 1RM was initiated. The subjects accomplished three bouts of fatigue stimulation until exhaustion, with one min resting between each bout. A Weird metronome signaled the start of the movement every third second during the fatigue stimulation.

When the fatigue stimulation bouts were finished, the subjects accomplished tests of recovery after 1,3,5,7,9,11,13,15,17,20,23,26 and 30 minutes. When the subjects had regained their MVC_{50} and MVIC to baseline levels, the session was ended. The subjects stayed passive (seated in the knee extension apparatus) during the recovery period.

MuscleLab

In order to measure the dynamic and isometric muscle strength, the MuscleLab system 4010/4020e (Ergo test Technology, Langesund, Norway) was used. MuscleLab is designed to use the most common type of force sensor, and during the present study the load cell (333A) was used in both isometric and dynamic contractions. One of the variables in the dynamic contractions was power (P), and for this purpose a linear encoder was used in combination with the force transducer. The linear encoder measure motion as a function of time together with the load cell, and the MuscleLab Software then calculates distance, velocity and power. The MuscleLab 4010/4020e got installed to the leg extension apparatus (Fig. 3). Using MuscleLab 4010/4020e claims some calibration. We fastened a known weight at the power cell, in this case 80kg, and the load was set to 80kg (Fig. 6). Calibrating the linear encoder means defining the position to zero at the starting point of the extension. MuscleLab 4010/4020 and Microsoft Excel (Version 2007; Microsoft Corporation, USA) were used in all calculations.

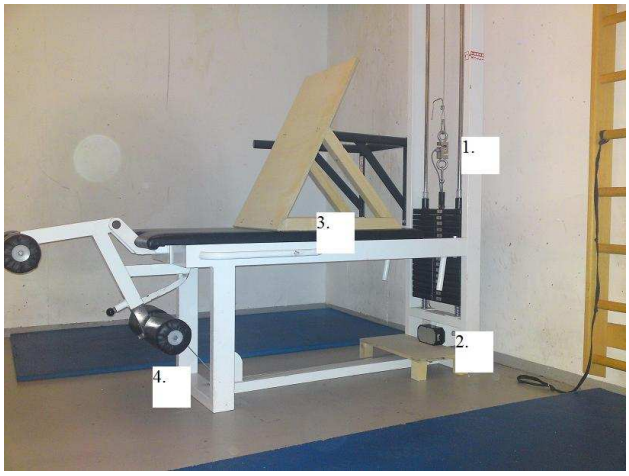

Figure 3: MuscleLab setup at the knee extension apparatus. 1. Power cell attached to the wire. 2. Linear encoder attached to the load plates. 3. Backrest. 4. Leg adjustment.

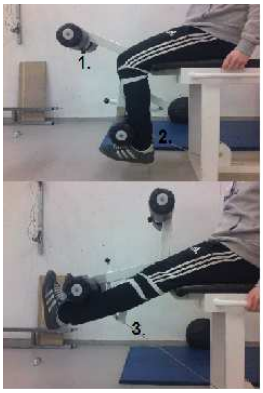

Figure 4: 1. Starting position. 2.Lever arm placed at superior extensor retinaculum. 3. Full extension (0^{o})

Figure 5: Locking device, used during the isometric measurements.

Figure 6: Calibration of the power cell.

Data handling and calculations

All the measurements, both MVC_{50} and MVIC were calculated from the starting position (knee angle at 90^{o}) seated in the leg extension apparatus. The ending point in the dynamical movement was defined at full extension (knee angle at 0^{o}) (Fig. 4). The superior side of the subjects' ankle was pressing against the pads, and the knee in line with the rotation cam of the machine.

The results of the MVC_{50}, was expressed as peak power (PP_{50}), time to peak power ($TtPP_{50}$), peak force (PF_{50}) and time to peak force ($TtPF_{50}$). Start of the measurements where considered to be when there was one successive increasing positive measurements of velocity higher than 0.010 m/s, followed by an increase in measured position until PP_{50} and PF_{50} was achieved. End of the measurements was considered to be at highest measured values in force and power in the concentric phase of the extension.

During the MVIC test seated in the leg extension apparatus, the subjects kept the contraction for 3 seconds. Measurements of the MVIC were expressed as maximal force value. During the isometric test the plate loaded knee extension apparatus was locked (Fig. 5).

Different customizations where made to ensure reproducibility and similarity of the movement for each athlete. We wanted to limit the compensatory movements, so the MVC and MVIC measurements could be related only to the force generated in the muscles normally involved in the leg extension exercise. Seated in the leg extension apparatus the athletes where stringed at the hip with a belt system, and had support in a backrest. The arm of the knee extension apparatus was placed at the superior extensor retinaculum (Fig. 4).

Statistical analyses

All data were checked for normality by use of the Shapiro-Wilks test and are presented as mean and standard deviation (*SD*). To examine within group effects of ST on the power and force variables investigated, the paired samples *t*-test procedure was performed when there were only two repeated measurements on the variable. A one-factor analysis of variance (ANOVA) was performed when there was three repeated measurements on the variable involved, e.g. when comparing PP_{50} in the baseline with PP_{50} with and without use of ST. A two-factor within subjects ANOVA was carried out when testing for differences between use and non-use of ST during the repeated measurements of PP_{50} and PF_{50} after fatiguing the knee extensors. These analyses, if significant, were followed-up by paired samples *t*-test and

adjusted for multiple comparisons by use of the Bonferroni correction. Statistical significance was set at $p < 0.05$.

Sample size estimation was made on the basis of PP_{50} in a pilot study and calculated according to Kleinbaum et al. (1998: 29) to find the minimum sample size required to detect a difference of 1.5 *SD*. With a level of significance at $p < 0.05$ and a power on 0.8, < 7 persons were needed to reveal a difference of 176 N.

Also, intraclass correlation coefficients (*ICC*) were calculated for the two dependent variables PP_{50} and PF_{50} in the pilot study. Four subjects with similar characteristics as the subjects in this study participated in the pilot study. Four repeated measurements of PP_{50} and PF_{50} by use of the MuscleLab showed an average *ICC* of 0.96 and 0.92, respectively. The values of *ICC* for single measures were 0.86 and 0.74 for PP_{50} and PF_{50}.

RESULTS

Differences in Peak Power and Time to Peak Power

The power measurements in the MVC_{50} for the whole group are presented below (Fig. 7). The subjects' individual peak power scores during the MVC_{50} are presented in Fig.8.

No significant differences were revealed in any of the scores obtained in baseline and recovery tests, with or without ST in PP_{50} ($F\ 2/15=0.05$; $P=0.95$) mean PP_{50} ($t5=0.02$; $P=0.99$) and TtPP50 ($F\ 2/15=0.27$; $P=0.77$).

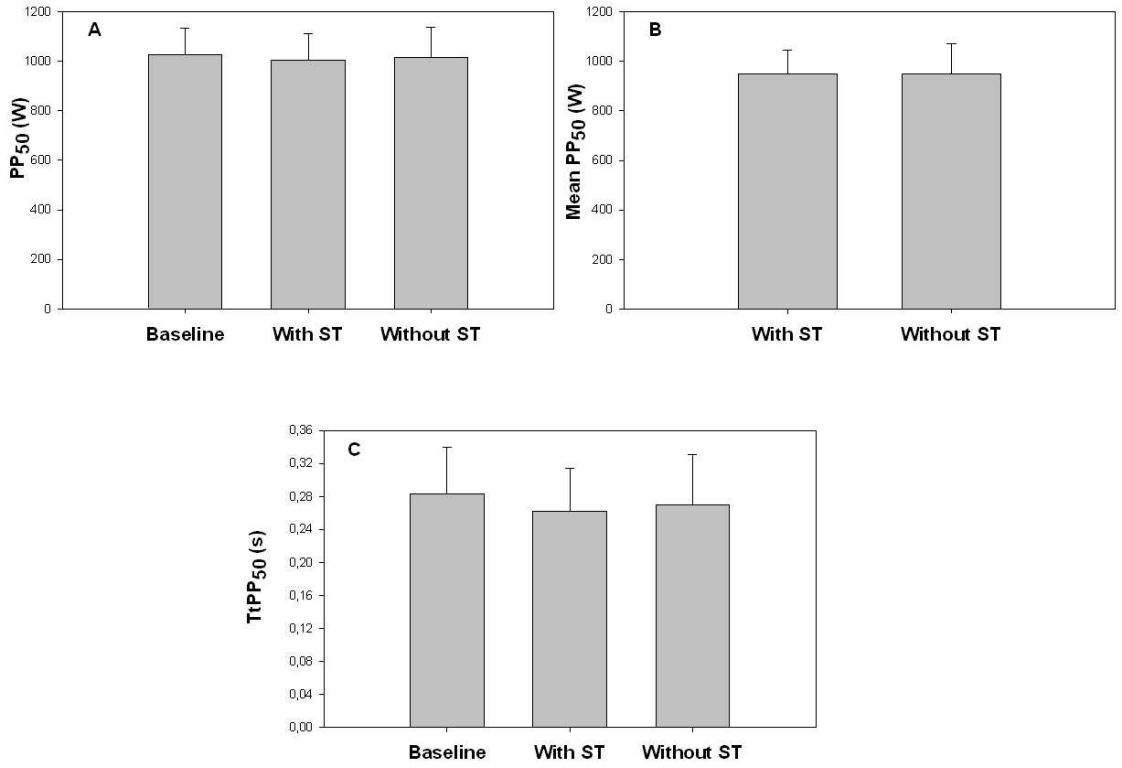

Figure 7: A: The subjects highest measured PP_{50} at baseline, as well as with and without ST in the recovery test. B: The subjects mean PP_{50} during the recovery test with and without ST. C: The subjects $TtPP_{50}$ during the highest measured PP_{50} value at baseline, as well as with and without ST. All variables are presented as means ± SD (N=6).

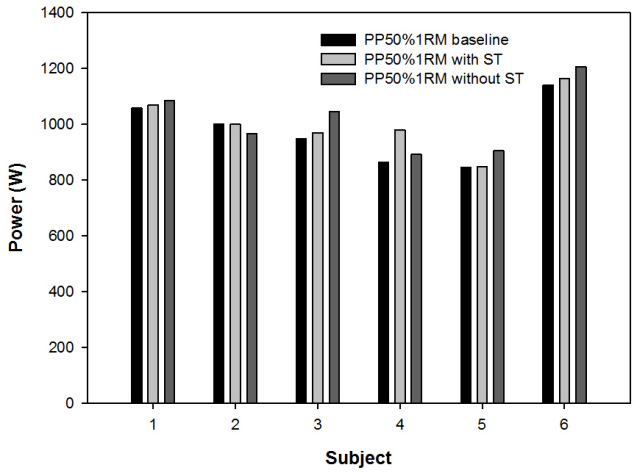

Figure 8: Peak Power values at MVC_{50} for each subject at baseline, as well as with and without ST in the recovery test.

The PP_{50} in each of the repetitions during the two recovery tests, with and without ST, are given in Fig. 9 for all subjects pooled. There was a significant effect of time in the PP_{50} during the recovery test, (F7/35 = 3.20, P = 0.01), but no effect of ST (F1/5=0.16, P=0.70) or interaction between time and ST (F7/35=0.26, P=0.97) were revealed. Figure 9 is based on the first 15 min of the recovery tests, because there was missing values later on in these time-series due to different end-points for each subject. Each subjects´ individual PP_{50} scores during the two recovery tests are shown in Fig. 10, with their own baseline PP_{50} score as the reference line. At average it took the subjects 12.5 ± 6.1 min and 10.0 ± 4.5 min to return back to the baseline PP_{50} score during the recovery tests with and without ST, respectively. The time it took to recover PP_{50} back to baseline level did not differ between these two conditions (t5 = 1.01, P=0.36).

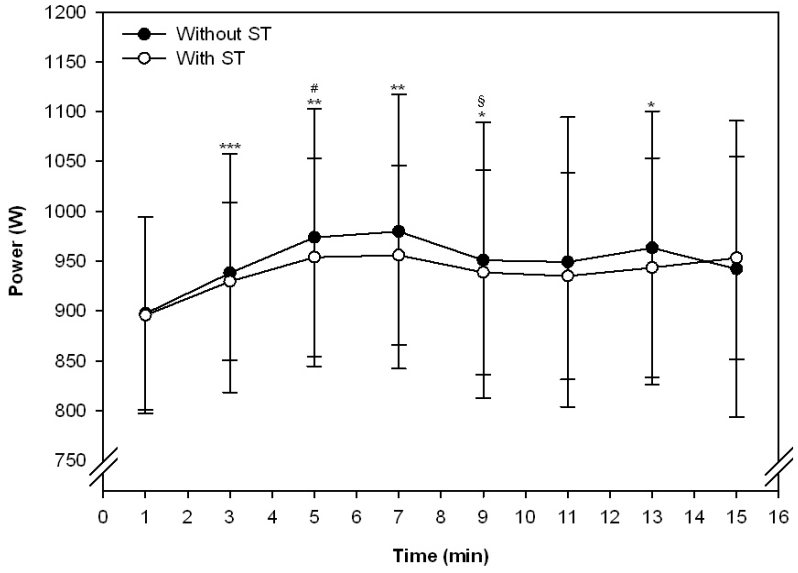

Figure 9: The mean power measurements in a MVC_{50} for all subjects from 1 min to 15 min during the recovery test (N=6). *= Significant different from the first measurement for all subjects and both conditions pooled; *P<0.05, **<0.01 ***<0.001. $^{\#}$=Significant different from the second measurement for all subjects and both conditions pooled; $^{\#}$P<0.05. §= Significant different from the third measurements for all subjects and both condition pooled; §P<0.05. Only observations during the first 15 min, which are common for all subjects, are given in the figure. The subjects had different end-points.

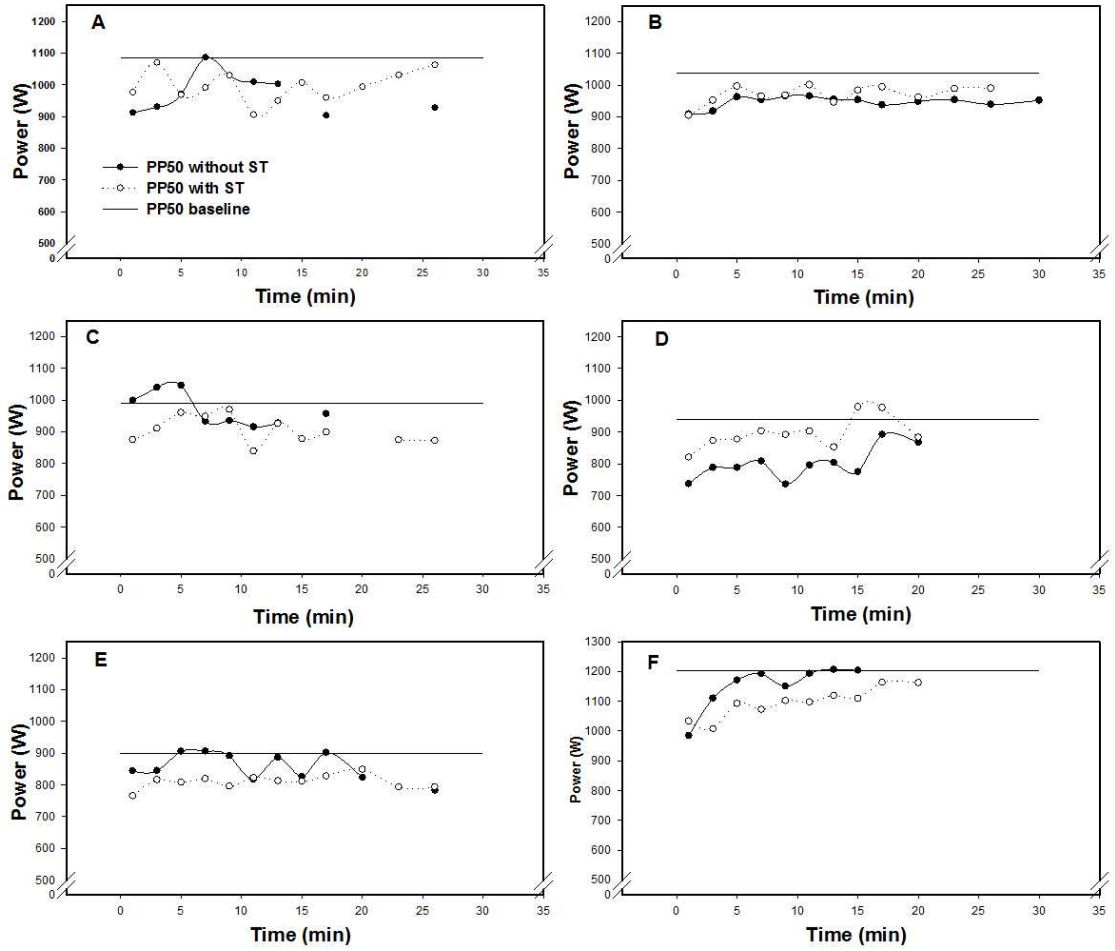

Figure 10: The figure shows each subjects power measurements in a MVC_{50} during repeated measurements every other minute in the recovery tests with or without ST. The figure shows the values from the 1st minute until the recovery test was ended. The straight line indicates the subjects PP_{50} value in a MVC_{50} at baseline.

Differences in Peak Force and Time to Peak Force

The force measurements in the MVC_{50} for the whole group are presented below (Fig. 11). The subjects' individual peak force scores during the MVC_{50} are presented in Fig.12.

No significant differences were revealed obtained from the baseline scores, with or without ST in PF_{50} during the recovery tests (F 2/15=0.16; P=0.85). The subjects mean PF_{50} proved to be significant higher with ST than without during the recovery test (t5=2.77; P=0.04), and the $TtPF_{50}$ was significantly higher than the scores obtained in baseline, compared to the test without ST during the recovery test (F 2/15=3.94; P=0.04).

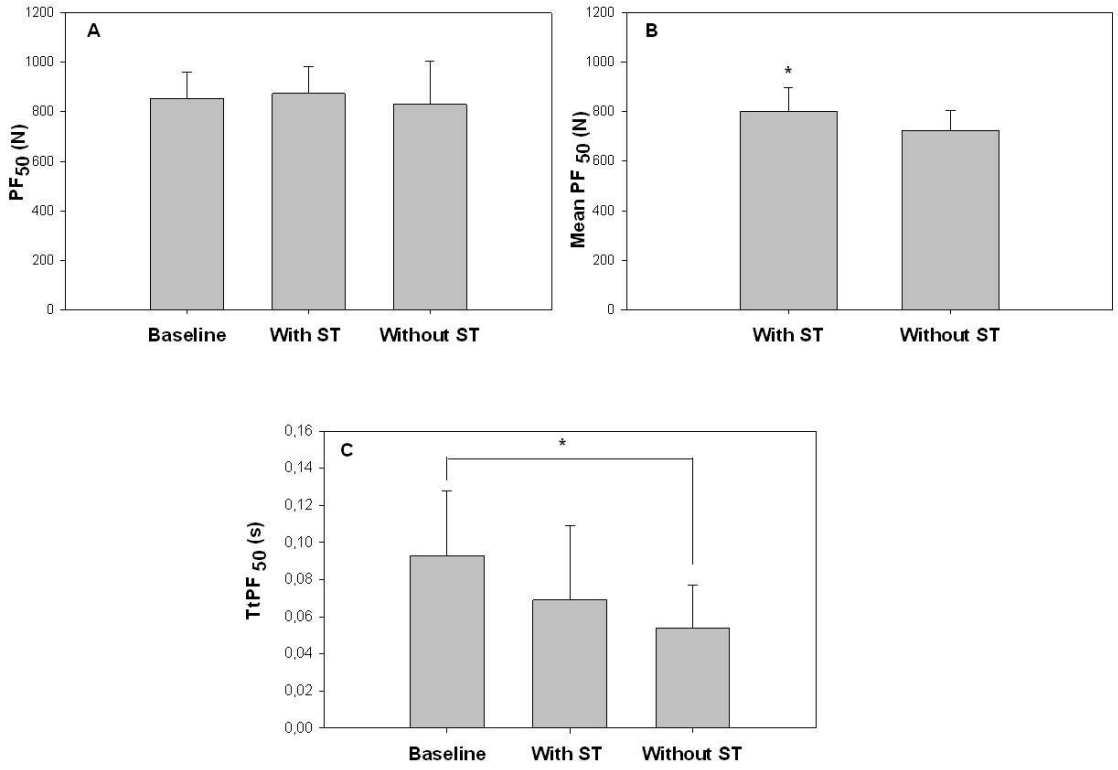

Figure 11: A: The subjects highest measured PF_{50} at baseline, as well as with and without ST in the recovery test. B: The subjects mean PF_{50} during the recovery test with and without ST. C: The subjects $TtPF_{50}$ during the highest measured PF_{50} value at baseline, as well as with and without ST. All variables are presented as means ± SD (N=6).

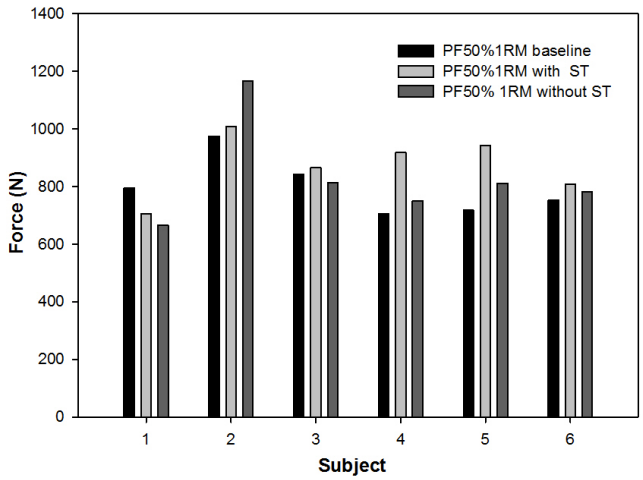

Figure 12: Peak force values at MVC_{50} for each subject at baseline, as well as with and without ST in the recovery test.

The PF_{50} in each of the repetitions during the two recovery tests, with and without ST, are given in Fig. 13 for all subjects pooled. There were no significant effect of time (F7/35=1.38, P=0.24), ST (F1/5=4.42, P=0.09), or the interaction between time and ST (F7/35=1.33, P=0.27) in the PF_{50} during the recovery test. Figure 13 is based only on the first 15 min of the recovery test, in order to include all subjects. However, on average it took the subjects ~19 min to recover PF50 back to baseline level with use of ST during the recovery test and, therefore, we had to perform a separate paired samples *t*-test between with and without ST to test for different time in returning PF_{50} back to baseline level. This analyze revealed significant longer recovery period with use of ST (Mean: 18.5 min; SD: 7.3) compared to without use of ST (Mean: 8.7 min; SD:4.5; t5=3.25, P=0.02).

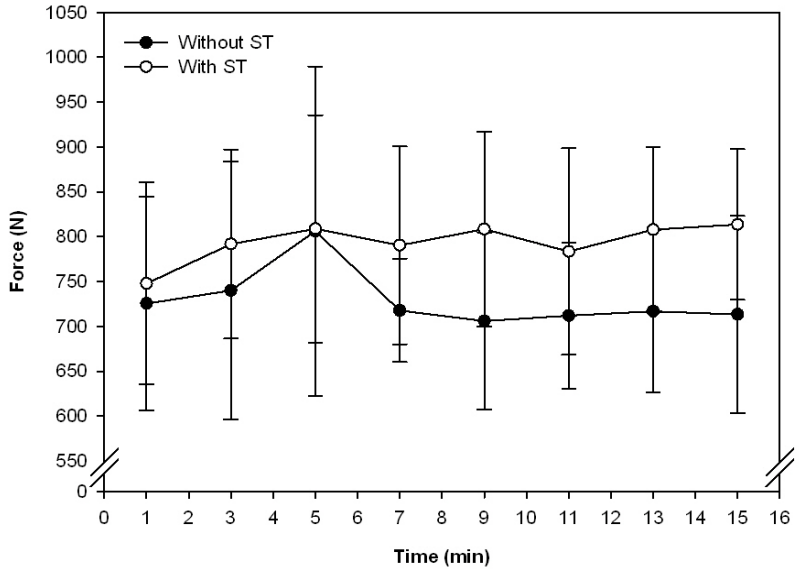

Figure 13: The mean force measurements for all subjects at MVC_{50} during the recovery test (N=6). Only observations during the first 15 min, which are common for all subjects, are given in the figure. The subjects had different end-points. Note: The subjects reached their baseline PF_{50} scores with ST later than after 15 min (see text for more details).

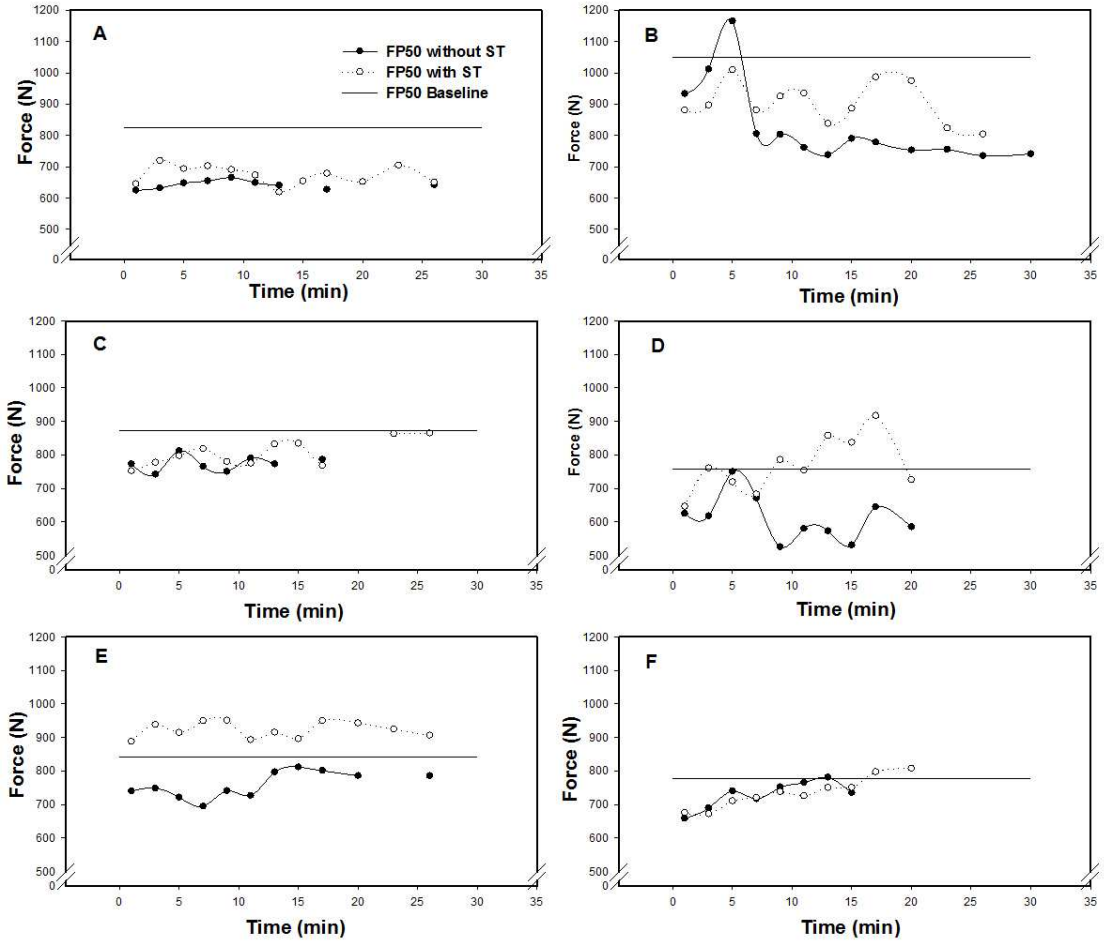

Figure 14: The figure shows each subjects force measurements in a MVC_{50} during repeated measurements every other minute in the recovery period with or without ST. The figure shows the values from the 1st min until the recovery test was ended. The straight line indicates the subjects PF_{50} value in a MVC_{50} at baseline.

Differences in isometric maximal voluntary contraction Force

The force measurements in the MVIC for the whole group are presented below (Fig. 15)

The MVIC at baseline proved to be significantly higher than the MVIC scores during the recovery test without ST ($F2/10=5.20;P=0.03$).

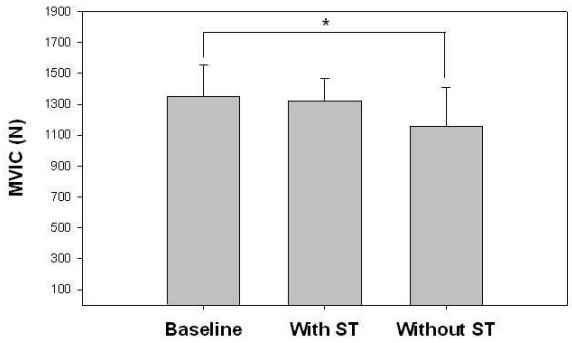

Figure 15: The Maximal Voluntary Isometric Contractions obtained at baseline, as well as with and without ST. The values are presented as means and ± SD (N=6). *=Significant higher score in baseline MVIC (P=0.03).

DISCUSSION

Main findings

The main findings in this study showed a significant delayed time of recovery, with use of ST compared to without use of ST, during PF_{50} in each of the repetitions during the two recovery tests, and no significant differences in PP_{50}, and $TtPP_{50}$ with or without ST were proved.

Differences in peak power and time to peak power

No significant differences were proven in this study, upon any of the scores obtained in baseline and during the recovery tests, with or without ST in $PP_{50,}$ mean PP_{50} and $TtPP_{50}$. Escher et al. (1998) reported the same observation, with no significant differences in reaction time and force during test with and without ST. The MVC_{50} measurements in this study showed that four of the subjects achieved a higher PP_{50} without ST according to the PP_{50} measurements with ST in the recovery test (Fig.8), but the findings did not differ significantly.

The PP_{50} in each of the repetitions during the two recovery tests, with and without ST, proved a significant effect of time in the PP_{50} during the recovery test, but no effect of ST, or interaction between time and ST were revealed. At average it took the subjects 2.5 min longer to return back to the baseline PP_{50} score during the recovery tests with ST, compared to without ST. Despite the difference, it was not found significant.

Differences in peak force and time to peak force

No significant differences were revealed obtained from the baseline scores, with or without ST in PF_{50} during the recovery tests, but the subjects mean PF_{50} proved to be significant

higher with ST than without during the recovery test, and the $TtPF_{50}$ was significantly higher than the scores obtained in baseline, compared to the test without ST during the recovery test. The differences in $TtPF_{50}$ might have several causes. The baseline tests were the first ones accomplished, and the significant improvement from baseline to the tests without ST, might be due to an improved technique in the leg-extension exercise. Four off six subjects' achieved higher PF_{50} values with ST than without ST, but it did not differ significantly (Fig.12).

The PF_{50} in each of the repetitions during the two recovery tests, with and without ST, proved no significant effect of time or the interaction between time and ST in the PF_{50} during the recovery test. But because that the above mentioned findings were based only on the first 15 min of the recovery test (in order to include all subjects), a separate paired samples *t*-test between with and without ST to test for different time in returning PF_{50} back to baseline level was performed. The analyze revealed a 9.5 min significant longer recovery period with use of ST, compared to without.

The measurements according to MVIC, proved a significant higher force at baseline, compared to MVIC force during the test without ST.

Summary considerations

It could be reasonable to believe that ST exerts a negative effect upon performance, and increase the time of recovery after muscle fatigue. However, many studies have failed to prove a decreased performance (Van Duser & Raven, 1992; Escher, 1998; Edquist, 2004; Karlsen, 2004), and as mentioned initially vigorous literature searches have not proven successful in finding any studies examining the effect of ST upon recovery time. Most of the studies have proved increased HR (Guggenheimer, 1991; Edquist, 2004), increased secretion of epinephrine and norepinephrine (Cryer et al., 1976; Guggenheimer, 1991; Lumbardo, 1998; Edquist, 2004), and raised levels of lactate at given workloads or efforts (Van Duser & Raven, 1992). Several studies have indicated, that raised levels of lactate are observed with ST compared to the same tests without ST. It is also proved increase of H^+ ions and P_i when raised levels of lactate, is observed. The metabolites H^+ and P_i has been suggested as possible sites for pheripheral fatigue and a decreased performance, when they interfere the Ca^{2+} binding to troponin C (Vøllestad 1997; Westerblad & Allen, 2002). Vøllestad (1997) points to that the interference of raised metabolites levels, results in fewer binding sites to the myosin at the actin, resulting in a decreased force per cross-bridge (Åstrand et al., 2003). Considering this, it is however surprising that no studies have achieved to prove significant

differences in performance with and without ST. A possible weakness of the studies is that all the tested subjects are regular ST users over several years, and it is tempting to speculate, whether the effect of ST exerts a greater impairment to non regular users of ST. In addition, you could imagine that the differences had been easier to prove *in vitro*, compared to the tests on MVC, endurance, isotonic or isometric contractions, which have several limitations.

Many authors (Bigeland-Ritchie et al., 1983; Löscher et al., 1996; Taylor et al.,2000) claims that fatigue during substained muscle actions, might be due to both pheripheral and central fatigue. However, fatigue has mainly proved to be due to peripheral factors, when there is a sufficient rest between each action (Bigeland-Ritchie et al., 1986). Simultaneously Vøllestad (1997) refers to that MVC might be due to both central and peripheral fatigue. In light of these findings it is difficult to state the exact underlying mechanism for the fatigue shown in this study. Taken Westerblad & Allen (2002) findings in consideration, it is tempting to suggest that the fatigue mainly were due to peripheral factors. It might be factors such as insufficient supply of energy through the aerobic/anaerobic pathways, metabolic factors such as lactate, H^+ and P_i, reduced Ca^{2+} release from SR and the decreased Ca^{2+} sensitivity at the troponi C, but as noted it will be only speculations.

Limitations

In the present study, as numerous other studies that includes MVC, there are limitations. Vøllestad (1997) points to that psychological factor such as motivation can vary within the group tested. The task they were given during the MVC was to perform maximal effort. For the author in this investigation, there is no guarantee that the subjects managed to perform a maximal effort with proper technique at each MVC, which is a possible site for differences in the measurements. The subjects were told not to exercise vigorously the day before testing, but this is difficult to completely control. In addition, there might be different muscle fiber composition within the group tested. Bigeland-Ritchie et al. (1986) refers to that the impairment of the performance resulting from muscle fatigue, might differ according muscle fiber type.

During the days of testing, the subjects had a tight match schedule, which also may have inhibited the test results. None of the tests were conducted the day after a match. However, it is a possibility that the subjects not were completely recovered when performing the actual test in this study.

The leg extension apparatus applied in this study was old, and the resistance of the levers, pulleys and cams involved may have differed.

The sample size estimation was made on the basis of PP_{50} in a pilot study and calculated according to Kleinbaum et al. (1998: 29) to find the minimum sample size required to detect a difference of 1.5 *SD*. However, it could have been more appropriate to calculate sample size according to an ANOVA design.

CONCLUSION

During the present study, the main focus of interest was to investigate the effect of ST upon recovery time. Specifically we wanted to see if use of ST would lead to delayed time of recovery in muscular force and power, following a fatiguing leg extension exercise. We also wanted to see if the PF and PP would be lower, and TtPF and TtPP would be higher, with use of ST than without.

Some of our findings indicated a conferment of the hypothesis, for example the significant observation with longer time of recovery back to the obtained baseline PF_{50} scores with ST. Another observation was that the PP_{50} in each repetitions during the recovery test for all the subjects, pictured a small difference in the PP_{50} values achieved, respectively with and without ST, and higher PP_{50} values were found without ST, than with ST.

Another observation was that the PF_{50} measurements during the recovery period with and without ST, pictured bigger differences than between the PP_{50} measurements during the recovery period, with and without ST. The reason for this difference is unknown, but there might seem as the interaction between ST upon force and power in this investigation differs.

A conclusion for this investigation is that muscle power and force does not seem to differ significantly with or without ST. The differences in time of recovery with and without ST was proved significant in the force tests, but not in the power tests. The $PP_{50,}$ PF_{50}, $TtPP_{50}$ and $TtPF_{50}$ do not seem to be either significantly improved or impaired with use of ST.

On behave of these findings, it is difficult to state the exact effect of ST upon recovery time, because there is no certain pattern in the findings, and further research is required.

References

BENOWITZ, NL. Pharmacologic aspects of cigarette smoking and nicotine addiction. *N.Engl. J. Med.* 319:1318-1330, 1988.

BIGELAND-RICHIE, B. CAFARELLI, E. VØLLESTAD, NK. Fatigue of submaximal static contractions. *Acta Physiol Scand Suppl* 556: 137–148, 1986.

BIGELAND-RITCHIE, B. FURBUSH, F. WOODS, JJ. Fatigue of intermittent submaximal voluntary contractions: central and peripheral factors. *J Appl Physiol* 61: 421–429, 1986.

BRUTON, JD. LÄNNGREN, J. WESTERBLAD, H. Mechano-sensitive linkage in excitation contraction coupling in frog skeletal muscle. *J Physiol* 484: 737–742, 1995

CRYER, PE. HAYMOND, MW. SANTIAGO, JV. SHAH, SD. Norepinephrine and epinephrine release and adrenergic mediation of smoking-associated hernodynamic andmetabolic events. *New Engl J Med* 1976; 295: 573-7.

ALLEN, DG. LAMB, GD. WESTERBLAD, H. Skeletal Muscle Fatigue: Cellular Mechanisms. *Physiol. Rev*. 88: 287-332, 2008.

EDWARDS, SW. GLOVER, ED. SCHROEDER, DL. The effects of smokeless tobacco on heart rate and neuromuscular reactivity in athletes and nonathletes. *Physician Sportsmed.* 15 (7):141-147, 1987.

EDAWARDS RHT. HILL DK. JONES DA. MERTON PA. Fatigue of long duration in human skeletal muscle after exercise. *J Physiol* 272: 769–778, 1977.

ESCHER, SA. TUCKER, AM. LUNDIN, TM. GRABINER, MD. Smokeless tobacco, reaction time, and strength in athletes, Medicine & Science in Sports & Exercise. Issue: Volume 30(10), October 1998, pp 1548-1551

GLOVER, ED. SCHROEDER, KL. HENNINGFIELD, JE. SEVERSON, HH. CHRISTEN, AG. An interpretative review of smokeless tobacco research in the United States: part II. *J. Drug Educ.* 19:1-19, 1989.

GRITZ, ER. BAER-WEISS, V. BENOWITZ, NL. VAN VUNAKIS, H. JARVIK, ME. Plasma nicotine and cotinine concentrations in habitual smokeless tobacco users. *Clin. Pharmacol. Ther.* 30:201-209, 1981.

HILL, CA. THOMPSON, MW. RUELL, PA. THOM, JM. WHITE, MJ. Sarcoplasmic reticulum function and muscle contractile character following fatiguing exercise in humans. *J Physiol* 531: 871–878, 2001.

KLEINBAUM, DG. KUPPER, LL. MULLER, KE. NIZAM, A. *Applied Regression Analysis and Other Multivariable Methods*. 3rd ed. Pacific Grove, CA: Duxbury, 1998. p. 29.

KSIR, C. SHANK, M. KRAEMER, W. NOBLE, B. Effects of chewing tobacco on heart rate and blood pressure during exercise. *J. Sports Med.* 26:384-389, 1986.

KRAEMER, WJ. FLECK, ST. Strenght training for young athletes. Champaign, IL: Human kinetics. (1993).

LANDERS, DM. CREWS, S. BOUTCHER, SH. SKINNER, JS. GUSAFSEN, S.The effects of smokeless tobacco on performance and psychophysiological response. *Med. Sci. Sports Exerc.* 24:895-903, 1992.

LOMBARDO, JA. Stimulants and athletic performance (part 2): cocaine and nicotine. *Physician Sportsmed.* 14(12):85-90, 1986.

LÖSCHER, WN. CRESSWELL, AG. THORSTENSSO. Central fatigue during a long-lasting submaximal contraction of the triceps surae. *Exp Brain Res* 108: 305–314, 1996.

NAKAJIMA,S. NAKAJIMA, Y. PEACHEY, LD. Speed of repolarization and morphology of glycerol-treated frog muscle fibres. *J Physiol* 234: 465–480, 1973.

SCHROEDER, KL. CHEN, MS. Smokeless tobacco and blood pressure. *N. Engl. J. Med.* 312:919, 1985.

SILVERSTEIN, P. Smoking and wound healing. *Am. J. Med.* 93:22S-24S. 1992.

SIRUS Norwegian Institute for Alcohol and Drug Research. *Norwegian Tobacco Statistics 1973–2006*. Oslo, 2007.

THOMAS, JR. NELSON, JK. SILVERMAN, SJ. *RESEARCH METHODS IN PHYSICAL ACTIVITY.* USA, HUMAN KINETICS, (2005).

VANDENBOOM, R. The myofibrillar complex and fatigue: a review. *Canadian Journal of Applied Physiology*, 29, 330-356. (2004).

VAN DUSER, BL. RAVEN, PB. The effects of oral smokeless tobacco on the cardiorespiratory response to exercise. *Med Sci Sports Exerc.* 24:389-395, 1992.

VØLLESTAD, NK. Measurement of human muscle fatigue. *Journal of Neuroscience Methods,* Volume 74, Issue 2, 27 June 1997, Pages 219-227.

WESTERBLAD, H. ALLEN, DG. Recent advances in the understanding of skeletal muscle fatigue. *Current Opinion in Rheumatology*, 14, 648-652. (2002).

ÅSTRAND, PO. RODAHL, K. DAHL, HA. STRØMME, SB. (2003). *Textbook of work physiology: physiological bases of exercise* (4th ed.). Leeds: Human Kinetics.