FACULTY OF MEDICINE AND HEALTH SCIENCES

DOES A TOTAL KNEE REPLACEMENT AFFECT MUSCLE RECRUITMENT DURING CYCLING

A PATIENT CONTROL STUDY

Eline Vanackere
Lore Van Loon

Promotor: dr. Roel De Ridder
Copromotor: Prof. dr. Tine Willems

A dissertation submitted to Ghent University in partial fulfillment of the requirements for the degree of Master of Rehabilitation Sciences and Physiotherapy.

Academic year: 2017 - 2018

GHENT UNIVERSITY

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LIST OF ABBREVIATIONS

ADL: Activities of Daily Living

BBS: Berg Balance Scale

BDC: Bottom Dead Centre

BF: M. Biceps femoris

BMI: Body Mass Index

CPM: Continuous Passive Motion

EMG: Electromyography

Hz: Hertz

KOOS: Knee Injury and Osteoarthritis Outcome Score

m: Meter

M: Musculus

MAP: Maximal Aerobic Power

ms: millisecond

MVC: Maximal Isometric Voluntary Contraction

NPRS: Numeric Pain Rating Scale

OKS: Oxford Knee Score

PCS: Physical Component Score

Q: Quadrant

RF: M. Rectus femoris

RMS: Root Mean Square

ROM: Range Of Motion

rpm: Rotations Per Minute

SENIAM: Surface Electromyography for the Non-Invasive Assessment of Muscles

SF-12: 12-item Short- Form Health Survey

SF-36: 36-item Short- Form Health Survey

ST: M. Semitendinosus

TDC: Top Dead Centre

TENS: Transcutaneous electrical nerve stimulator

TKA: Total Knee Arthroplasty

V: Volt

VAS: Visual Analogue Scale

VLO: M. Vastus lateralis obliquus

VMO: M. Vastus medialis obliquus

W: Watt

WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index

ABSTRACT ENGLISH

Background The prevalence of total knee replacements is increasing and indicates an important impact on Activities of Daily Living (ADL), such as cycling. Detailed evaluation of the muscle recruitment in those patients would potentially provide further information and insights. Consequently, rehabilitation protocols could be adjusted.

Objective To compare muscle activity patterns in patients following a total knee arthroplasty (TKA) to the non-operated limb of the same person and to a healthy control group.

Study Design Patient-control study.

Methods A total of 21 patients, approximately one year post-operative and 21 matched control subjects participated in this study. Participants performed a Maximal Isometric Voluntary Contraction (MVC), an isokinetic muscle strength test for knee flexion and extension and a cycling ergometer test. MVC of Musculus (M.) Rectus femoris, M. Vastus medialis obliquus, M. Vastus lateralis obliquus, M. Biceps femoris and M. Semitendinosus was measured against a manual resistance. Knee kinematics were registered during the cycling test, consisting of a step-protocol at progressive resistance levels of 50, 75, 100, 125 and 150 Watt (W) at 80-85 rotations per minute (rpm). One minute active recovery at 50W between each step was provided. Each power level lasted 20 seconds, during which the measured data was recorded. Surface Electromyography (EMG) were registered bilateral in patients and unilateral in controls during the three tests. Differences in onset, offset, duration, timing of peak value and peak value of the five muscles were analyzed, with a significance level set at $p<0,05$.

Results Significant group*power level interactions were found in this study comparing the affected leg of patients to the non-affected leg or to controls. A significant delayed onset for patients' affected leg was found for M. Rectus femoris at 150W ($p=0,008$) compared to controls. Moreover, for M. Vastus lateralis obliquus, a significant delayed peak value for patients was found at 50W compared to the non-affected leg ($p=0,025$) and to controls ($p=0,014$). At 150W, a significant earlier peak value was found for the patients' affected leg compared to the non-affected leg ($p=0,018$).

Observing the effect of power level, significant results were found. At onset, M. Biceps femoris ($p<0,001$) occurred earlier for increased power level. Later offset for increasing power levels was observed for M. Rectus femoris ($p=0,007$), M. Biceps femoris ($p<0,001$) and M. Semitendinosus ($p<0,001$). Moreover, significant longer duration for increasing power levels was found for M. Rectus femoris ($p<0,001$), M. Vastus lateralis obliquus ($p<0,001$), M. Biceps femoris ($p<0,001$), and M. Semitendinosus ($p<0,001$). Lastly, a significant higher peak value for increasing power levels was found for M. Rectus femoris ($p<0,001$), M. Vastus lateralis obliquus ($p<0,001$)), M. Vastus medialis obliquus ($p<0,001$), M. Biceps femoris ($p<0,001$) and M. Semitendinosus ($p<0,001$).

Isokinetic muscle strength of M. Quadriceps and hamstrings ($p<0,001$) measured on the Biodex, was significantly weaker in patients' affected leg compared to controls.

Conclusion Significant results for the interaction between power level and group were found.

No significant differences were found when comparing the affected leg of patients to the non-affected leg or to controls, regardless of the power level. Additionally, significant results of the power level were found. An earlier onset and later offset for increasing power levels were observed, resulting in a longer duration. At last, significant higher peak values for higher power levels were observed as well.

Keywords: Cycling, Electromyography, Total Knee Arthroplasty, Muscle Recruitment Pattern, Knee Kinematics

ABSTRACT NEDERLANDS

Achtergrond De prevalentie van totale knie prothesen stijgt en vertonen een belangrijke impact op de activiteiten uit het dagelijkse leven, zoals fietsen. Gedetailleerde evaluatie van de spierrekrutering in deze patiënten kan eventueel verder informatie en inzichten geven. Bijgevolg kunnen revalidatieprotocols aangepast worden.

Doelstelling De spieractiviteit bij patiënten met een totale knieprothese vergelijken met het niet-aangedane lidmaat van dezelfde persoon en met een gezonde controle groep.

Onderzoeksdesign Patiënt-controle studie

Methode 21 patiënten, ongeveer 1 jaar post-operatief, en 21 gematchte controles namen deel aan deze studie. Deelnemers voltooiden een Maximale Isometrische Willekeurige Contractie (MVC) test, een isokinetische krachttest en een fietstest op een ergometer. De MVC van M. Rectus femoris, M. Vastus medialis obliquus, M. Vastus lateralis obliquus, M. Biceps femoris en M. Semitendinosus werd gemeten tegen een manuele weerstand. Kinematica van de knie werd geregistreerd tijdens de fietstest die bestond uit verschillende niveaus van progressieve weerstanden, nl. 50, 75, 100, 125, 150Watt (W) aan 80-85 rotaties per minuut (rpm). Er werd één minuut actieve recuperatie aan 50W tussen twee niveaus gegeven. Elk niveau werd 20 seconden aangehouden, waarbij er dataregistratie plaatsvond. EMG werd tijdens de drie testen bilateraal geregistreerd in patiënten en unilateraal in controles. Verschillen in de start, einde, duur, timing van de maximale waarde en de maximale waarde van de vijf spieren werden geanalyseerd, met een significantieniveau gedefinieerd op $p<0,05$.

Resultaten Significante groep*wattage interacties zijn waargenomen in deze studie, waarbij de aangedane zijde van de patiënten vergeleken werd met de niet aangedane zijde of met een controle groep. Er was een significant later begin van de spieractiviteit bij de patiënten waargenomen voor M. Rectus femoris op 150W ($p=0,008$) vergeleken met de controlepersonen. Daarnaast was er op 50W voor M. Vastus lateralis obliquus een significant latere maximale waarde voor de patiënten vergeleken met hun niet aangedane zijde ($p=0,025$) en met de controlegroep ($p=0,014$). Op 150W was er een significant eerdere maximale waarde geobserveerd voor de vergelijking van de aangedane zijde met de niet-aangedane zijde van patiënten ($p=0,018$).

Ook voor het wattage effect werden er significante resultaten waargenomen. M. Biceps femoris ($p<0,001$) had een eerdere aanvang van spieractiviteit bij hogere wattages. M. Rectus femoris ($p=0,007$), M. Biceps femoris ($p<0,001$) en M. Semitendinosus ($p<0,001$) hadden een significant later einde van de spieractiviteit bij verhoogde wattages. Vervolgens is er een verlengde duur van de spieractiviteit waargenomen bij hogere wattages voor M. Rectus femoris ($p<0,001$), M. Vastus lateralis obliquus ($p<0,001$), M. Biceps femoris ($p<0,001$) en M. Semitendinosus ($p<0,001$).

Vervolgens is er ook een significant wattage effect op de maximale waarde waargenomen voor M. Rectus femoris ($p<0,001$), M. Vastus lateralis obliquus ($p<0,001$), M. Vastus medialis obliquus ($p<0,001$), M. Biceps femoris ($p<0,001$) en M. Semitendinosus ($p<0,001$), waarbij de maximale waarde hoger was bij hogere wattages.
De patiënten hebben een zwakkere isokinetische kracht ($p<0,001$), gemeten met behulp van de Biodex, van M. Quadriceps en de hamstrings vergeleken met controlepersonen.
Conclusie Significante resultaten werden gevonden voor de interactie tussen het wattage en de groep. Wanneer het aangedane been van patiënten vergeleken werd met het niet-aangedane been of met de controlegroep, werden er geen significante verschillen gevonden, ongeacht het wattage. Vervolgens werd er een significant vroegere start en later einde tijdens hogere wattages waargenomen, waardoor de spieren langer actief waren. Ten slotte, werden er ook significant hogere maximale waardes tijdens hogere wattages waargenomen.

Trefwoorden: Fietsen, Electromyografie, Totale Knieprothese, Spierrekruteringspatroon, Knie Kinematica

INTRODUCTION

Knee osteoarthritis is the most common reason for TKA surgery.[1] Austria (215/100 000), Finland (201/100 000) and Germany (188/100 000) had the highest number of TKA surgeries per 100 000 inhabitants in the European Union in 2013.[2] In fact, the number of knee replacements is showing an upward trend. TKA surgery is commonly performed in patients with knee osteoarthritis, rheumatoid arthritis or any other degenerative deformity affecting the knee.[3] Due to the aging of the population and the rising rate of obesity, expectations are that the number of people with knee osteoarthritis will continue to increase and therefore have a growing impact on the number of knee replacements.[1]

There are several indication criteria for TKA. First of all, a persistent pain after six months of conservative treatment, difficulty with ADL and decreased mobility must be present.[1, 3] Subsequently, radiographic changes such as narrowed joint space, osteophytes, bone cysts, squaring of condyles and bone sclerosis are apperceived.[3] These radiographic changes show an end-stage degenerative knee joint disease.[3, 4] Additionally, age and weight can influence the decision of TKA surgery. Young and middle-aged patients with knee osteoarthritis are indicated to start with a non-operative treatment. Moreover, studies show over 50% reduction of knee osteoarthritis with a decrease of the body mass index (BMI), which result in a decrease in load bearing to the knee.[3] Lastly, for conducting the surgery, it is important that the patient has a good current health status.[1, 3] When the patient meets all selection criteria for a knee replacement, the type of prosthesis needs to be selected in consultation with the patient, namely a partial or a total knee arthroplasty.

Before surgery, the patient will be informed about the surgery and long rehabilitation process. Main goals of rehabilitation are reducing pain and edema, improving range of motion (ROM), muscle strength, muscle endurance, neuromuscular control, aerobic capacity and ADL.[5-7] At this moment, there is no generally accepted rehabilitation protocol for patients after TKA. In fact, the rehabilitation protocol often depends upon the institution or surgeon.[8] Typically, a standard protocol is divided into different phases and it is indicated to start within 24 hours after surgery.[9] In the early stages, therapy generally focuses on pain, ROM and strength.[5] Pain can be treated with circulatory exercises, which also contributes to an increased blood flow. Additional methods to reduce the pain are pain medication, ice and elevation.[10] Furthermore, mobilization techniques and angular movements can improve ROM.[5] Besides Continuous Passive Motion (CPM) [11] and stretching, active ROM exercises can be advised to reach the full ROM earlier. Another commonly used method is ergometer cycling with adjustable seat height.

Due to an acute protective response following injury, neuromuscular inhibition can arise. Therefore, disinhibitory modalities (Transcutaneous electrical nerve stimulator (TENS), cryotherapy, vibration) and traditional strength exercises of the most important muscles, namely M. Quadriceps, hamstrings, hip abductors and hip adductors are indicated.[12, 13]

Kuntze G. et al. (2015)[14] studied multi-muscle activation strategies during walking in female patients following TKA. The authors conclude that the muscle activation patterns following a knee replacement were significantly altered for M. Vastus medialis obliquus and M. Biceps femoris. They found a delayed onset after heel strike and a prolonged muscle activation at mid stance for both muscles, aligning the activation of the M. Biceps femoris with the M. Quadriceps. In the second half of stance M. Vastus medialis obliquus, M. Vastus lateralis obliquus and M. Rectus femoris were active, indicating that activation changes are not restricted to individual muscles but involve changes across muscle groups. In addition, an absence of activation of M. Biceps femoris was seen during late stance. During toe off, a reactivation of this muscle occurred, in contrast to the control group.

In regard to muscle activation and co-activation during five-time-sit-to-stand in patients before and after undergoing TKA, Davidson BS. et al. (2013)[15] concluded that patients were slower to complete the five-time-sit-to-stand, unloaded the operated leg and showed higher M. Quadriceps/hamstrings co-activation when sitting. This indicates that the rehabilitation program needs to include training movement- and activation patterns.

Yoshida Y. et al. (2013)[16] found a significantly lower muscle recruitment in the M. Quadriceps of the operated limb during loading response three months following TKA compared to the non-operated limb and healthy controls. This gait analysis showed no differences in muscle recruitment patterns in the co-contraction of M. Quadriceps and hamstrings. The weakness of the M. Quadriceps is related to deficits in voluntary muscle activation and muscle atrophy. This research suggests retraining muscle recruitment patterns to increase relative M. Quadriceps recruitment and lessen the recruitment of the hamstring muscles during gait.

If the pain is alleviated and the ROM is improved, the patient can move on to the next phase. Strength exercises can be increased in intensity and functional training can be performed. Eventually, training will mainly focus on functional capacities as prioritized by the patient, such as walking, climbing stairs, standing up from a chair and cycling.[5]

For most patients, being able to cycle again after surgery is important. It is a means for transportation or recreation. Besides, cycling can be a tool to improve ROM, demonstrating its importance during rehabilitation.

During cycling, various muscles are active. The most important muscles of the lower limb are M. Gluteus maximus, M. Quadriceps, the hamstrings, M. Tibialis anterior and M. Triceps surae. Muscle recruitment during cycling can be visualized using a 360° crank cycle. This cycle is illustrated in figure 1.

The cycle is divided into four 90° quadrants. The first quadrant (Q1) starts at 0°, representing the Top Dead Centre (TDC) and ends at 90° in forward direction. Subsequently, the second quadrant (Q2) is going from 90° until the Bottom Dead Centre (BDC), which corresponds to 180°. The first two quadrants represent the propulsive phase.[17] The third quadrant (Q3) initiates at BDC until 270°. The fourth quadrant ranges from 270° to TDC, i.e. the same point where Q1 starts. The final two quadrants represent the recovery phase.[17, 18] In each quadrant the respective muscle activity levels vary. To examine the timing of muscle activation, it is important to determine the starting (onset) and the ending (offset) crank angles of the EMG bursts.[19]

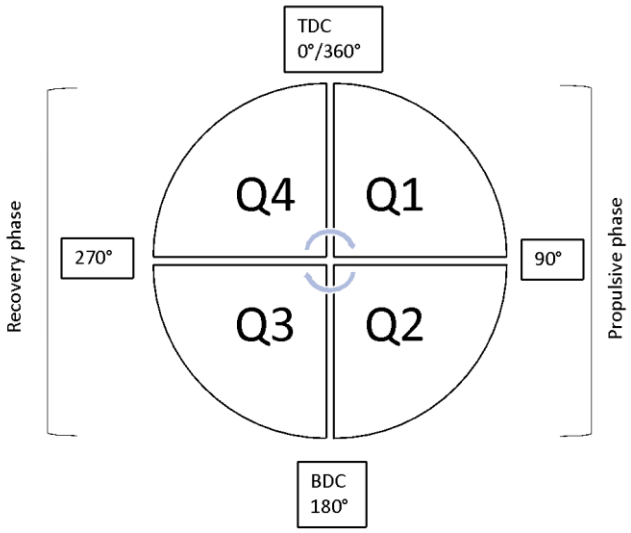

Figure 1: the 360° crank cycle

There is coordinated activation of the M. Quadriceps and hamstrings. During the propulsive phase, a relaxation of M. Quadriceps and activation of the hamstrings occurs in the extended knee. The opposite happens in the contralateral flexed leg, which is in the recovery phase at the same time.[20] This indicates the underlying reason for exercising an adequate muscle coordination following TKA.

These coordinative patterns can be analyzed through different methods, such as muscle activity and measurements of joint moments. The muscle activity during cycling is well studied. There is an influence of pedaling cadence[21], posture[21] and fatigue[17] on the coordinative pattern during cycling. First, changes in cadence will induce changes in the activity pattern. When cadence increases, the onset of the hip extensor muscles will occur earlier in the crank cycle. Furthermore,

during higher cadence, the agonists M. Gluteus maximus and M. Rectus femoris are active at the same time, resulting in longer duration in the crank cycle.[21] In addition, a change in posture can have an impact on the neuromuscular control system.[21] Changing the body geometry from seated to standing posture induces a significant increase in EMG activity of M. Gluteus maximus and M. Rectus femoris. Not only the activity level, but also the muscle coordination is affected. For both muscles, the onset occurs earlier, while the offset appears later for M. Rectus femoris. Fatigue has an impact on the muscle activity as well. Fatigue induces a significant reduction of pedaling cadence, which implies a change in muscle activity.[22]

A variety of outcome parameters are used for evaluating treatment effect. To assess pain, most important methods are the visual analogue scale (VAS)[2, 23] and the numeric pain rating scale (NPRS)[24, 25]. Swelling or edema is evaluated by measuring the circumference of the knee.[10, 24] Moreover, joint mobility is measured by the active and passive ROM.[2, 24, 26] Different measuring methods are indicated for the evaluation of knee flexion strength and knee extension strength.
A lot of studies investigated the strength of M. Quadriceps. Persistent weakness of M. Quadriceps has been demonstrated for over two years after TKA.[27] A few studies researched the strength of the hamstrings, but no conclusion could be made.[28] Some studies suggest that the strength of the hamstrings recovers faster than the strength of M. Quadriceps.[29, 30] Other studies suggest that hamstrings and M. Quadriceps strength recover at the same rate.[30, 31] Therefore, it is important to measure the muscle strength objectively. First, there is the MVC, which is an isometric contraction of the muscle group.[2, 32] Besides the MVC, another method to evaluate the strength is an isokinetic contraction.[2, 24] This is a dynamic contraction where the velocity of the movement does not change. Therefore, the maximal torque can be defined over the entire ROM. Additionally, strength can be measured during functional activities.

There are different methods available for evaluating neuromuscular control. First, there is a biomechanical method, where joint angles (kinematics) and joint moments (kinetics) are measured during movement.[33] Besides a biomechanical method, measuring different movements while measuring EMG is also a possibility, for example during the isokinetic contraction or functional movements.[34]
The functionality can be assessed through balance by the Berg Balance Scale (BBS) or the Single-leg stand test (SLST).[35, 36] Moreover, the 6-minute walk test and 30-second stair climb measures functional capacity through walking speed.[37]

Furthermore, self-reporting scales are frequently used following TKA. These are questionnaires answered by the patient. The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) measures disease-specific TKA outcomes, such as pain, stiffness, and physical function. Knee Injury and Osteoarthritis Outcome Score (KOOS) is based on the WOMAC, but also includes the outcomes of pain, ADL, sport and recreation function, and knee-related quality of life. Physical Component Score (PCS) of the 12-item Short- Form Health Survey (SF-12) or the 36-item Short- Form Health Survey (SF-36) are used for overall health assessment.[37] The Oxford Knee Score (OKS) has 12 items, assessing pain and function, specifically in patients following TKA.[38]

Most research examining muscle recruitment during functional activities considers only healthy people. As a result, there is lack of information about muscle activity patterns in patients following TKA.

The purpose of this study is to compare muscle activity patterns in patients following TKA to the non-operated limb of the same person and to a healthy control group.

In this study, three hypotheses were premised:

1) When increasing the power level on the cycling ergometer, differences emerge of the same group on the level of onset, offset, duration, timing of peak value and/or peak value.

2) During cycling, there are differences on the level of onset, offset, duration, timing of peak value and/or peak value when comparing the patients affected leg to the non-affected leg or when comparing the affected leg to a control subject.

3) During cycling, differences emerge regarding the interaction between power level and group.

METHODS

Study population

Twenty-one patients (8 males, 13 females) who received a total knee replacement in the Department of Orthopedics at the Ghent University Hospital and who were approximately one year post-operative at the time of investigation were contacted by phone, email, letter or visit. Patients were included when they met the inclusion criteria: 1) age between 50-75, 2) unilateral TKA surgery 9-15 months ago, 3) no history of injury or illness that can result in abnormal EMG results (stroke, nerve injury etc.), 4) no cardiac or pulmonary problems.

A control group (n=21; 9 males, 12 females) was recruited and matched for sex, age, BMI and leg dominance of the patient population. Subjects included in this group fulfilled inclusion criteria 1, 3 and 4 and an additional fifth criteria 'no history of a severe knee injury'.

Patients were tested bilaterally and the control group unilaterally. Leg dominance of the patients was requested to match to controls. When the patient identifies the limb with TKA as the dominant leg, the dominant leg of the matched control was examined. If the non-dominant leg of the patient was involved, the non-dominant side of the matched control was tested.

All 42 subjects signed a written informed consent before enrollment in this study. The testing results of 18 participants (9 patients, 9 controls) from an equal research of Ghyselinck R. and Ghillebert S. (2016) were included.

This study was accepted by the Ethical Committee of the Ghent University Hospital (N°: EC/2015/0725).

Information about both groups can be found in table 1.

		Group					
		Patients			Controls		
		Mean	Standard Deviation	Count	Mean	Standard Deviation	Count
Age (years)		64,76	7,043		62,48	6,058	
Post-op (months)		12,71	2,783		/	/	
BMI (kg/m^2)		30,32	3,981		26,12	2,699	
Seks	Male			8			9
	Female			13			12

Table 1: Patient and control group information

General design of the study

Following three tests were performed by all subjects while recording EMG signals: 1) MVC of M. Rectus femoris, M. Vastus medialis obliquus, M. Vastus lateralis obliquus, M. Biceps femoris and M. Semitendinosus. 2) An isokinetic muscle strength test for knee flexion and extension on a Biodex dynamometer (System 4 Pro, Biodex Medical Systems, USA, Inc., New York, USA). 3) A cycling test on a bike ergometer (Ergofit Cycle 400, Gymna, BE).

Testing protocol

Preparation: Skin preparation of the participants is an important first step for decreasing skin resistance. The skin was shaved, scrubbed and cleaned with ether. Following, bipolar Ag-Cl surface electrodes (Blue Sensor, Medicotest, Ballerup, Denmark) were placed according to the SENIAM (Surface Electromyography for the Non-Invasive Assessment of Muscles) guidelines [(39)] on M. Rectus femoris, M. Vastus lateralis obliquus, M. Vastus medialis obliquus, M. Biceps femoris and M. Semitendinosus. A reference electrode was placed on the fibula. The EMG signals were recorded with a 16-channel Noraxon Myosystem 1400A (Myosystem 1400A, Noraxon, USA, Inc., Arizona, USA), Noraxon Telemyo system 2400t G2 (Telemyo system 2400t G2, Noraxon, USA, Inc., Arizona, USA) or Noraxon DTS system (Direct transmission system, Noraxon,USA, Inc., Arizona, USA) with a frequency of 1000 Hertz (Hz). For minimizing cable movement artifacts and the risk of electrodes releasing from the skin, the cable and pre-amplifier were fixated with hypafix.[(40)]

Maximal Voluntary Contraction: M. Quadriceps and hamstrings contracted against a manual static resistance. Hereby, the starting position of the body was important. During the test of M. Quadriceps, the patient was sitting on the edge of the table. The subject had to perform a maximal single leg knee extension in a 70°-90° knee flexion position.[(40)] During the test of the M. Hamstrings, the subject had to perform an unilateral static knee flexion at 20°-30° knee flexion, while in prone position.[(40)] The patient was allowed to grasp the table. Measuring maximal strength through manual static resistance was obtained by slowly increasing strength in two seconds, followed by maximal strength for five seconds and finally reducing again for two seconds. This test was performed three times for each muscle group. During this test, five seconds of maximal strength were recorded with EMG.

Muscle strength: An isokinetic muscle strength test was performed on a Biodex dynamometer (System 4 Pro, Biodex Medical Systems, USA, Inc., New York, USA). The test consisted of five concentric/concentric repetitions of flexion/extension in the knee at a velocity of 180°/sec. This

protocol was performed twice. The first time, the subject had the possibility to practice the protocol. The second time, the test was performed at maximal strength to extract data from the muscles. This test was conducted bilateral for the patients and unilateral for the control group. A custom prepared foam was placed around the sensors of M. Semitendinosus and M. Biceps femoris to minimize the pressure on the sensors and avoid disturbance of the EMG signal.

Bike ergometer test: During the cycling test, an ergometer (Ergofit Cycle 400, Gymna, BE) with toe strap pedals was used. The height of the saddle is based on the leg inseam, which is the distance between the ground and perineum. The following formula was used to calculate the saddle height: saddle height = inseam x 0,883[41]

Three reflective skinmarkers were placed on the malleolus lateralis, epicondylus lateralis and trochanter major of the right leg. Due to these markers, a highspeed camera (Myovideo Pro, Noraxon, USA, Inc., Arizona, USA) placed at a distance of 2,0 meter (m) from the ergometer could record the kinematic movement of the knee. The subject was explained to keep the cadence between 80-85 rpm during the entire test. As warming-up, participants had to cycle three minutes at 50W. The testing interval of 20 seconds were recorded with EMG and video data. Following, the resistance was increased in steps of 25W until 150W. The subject had to maintain each testing interval for a minimum of 20 seconds, to ensure a valid number of pedal cycles. Between two testing intervals, the participants cycled one minute at a decreased resistance of 50W. Afterwards the subject was allowed to perform a cooling down of three minutes at a chosen resistance and cadence.

During the cycling test, heart rate and BORG-score were regularly checked to monitor the patient's exertion level. The test ended when the participant was too exhausted, could not pedal at 80 rpm or completed the test.

Data analysis

Data was analyzed using Noraxon Myoresearch software (version 3.10). All raw EMG signals were analog-digital converted (12-bit resolution) at 1000 Hz. All EMG signals were rectified and smoothed with a Root Mean Square (RMS) of 10 milliseconds (ms). Mean and maximal values of the middle three seconds of the MVC were calculated for all muscles. Results were normalized to the highest mean activity observed during the MVC trials, by reporting them as a percentage of the highest mean MVC EMG value. Muscle activity onset, offset and duration were determined for each muscle. The threshold for muscle activity was set at 10% of the EMG activity of MVC above the resting level. Onset was determined when the EMG signal exceeded 10% of the mean MVC value, offset when the

EMG signal dropped below 10%. During the cycling test, maximum values between onset and offset were calculated as well as the timing of these values.

During the cycling test, the knee angle was autotracked by the Noraxon Myoresearch software program (version 3.10). The supplementary angle was used in reference to 180°.

Statistical analysis

Differences in onset, offset, duration, timing of peak value and peak value of M. Vastus medialis obliquus, M. Vastus lateralis obliquus, M. Rectus femoris, M. Biceps femoris and M. Semitendinosus were analyzed between groups and power level using a statistical software package (SPSS 24). Data was analyzed using a linear mixed model with two levels (affected leg patient/control and affected leg patient/non-affected leg patient). Effects of three parameters were investigated (group, power level and group*power level interaction), corrected for age, sex and weight. Post-hoc analyses were performed with a Bonferroni correction. Differences in muscle strength of M. Quadriceps and hamstrings between patients and control subjects and between the affected and non-affected leg, were investigated by means of a one-way ANOVA test, with post-hoc independent T-tests. The significance level was set at $p<0,05$.

RESULTS

The number of patients and controls that completed the testing interval at a given power level are listed in table 2. All patients completed the test at 50W. Nineteen completed the test at 75W, 17 at 100W and 16 at 125W. Only 10 patients completed the test at 150W. The reasons for the premature stop were the inability to maintain the 80 rpm and exhaustion. For the control group, 18 subjects completed the test at 150W, one stopped the test at 125W and three completed the test at 100W.

	Patients	Controls
50 W	21	21
75 W	19	21
100 W	17	21
125 W	16	20
150 W	10	18

Table 2: Number of patients/controls that completed different stages of the ergometer test

Onset

An overall effect was found for the interaction between power level and group for M. Rectus femoris (p=0,002) (table 3). A significant group*power level interaction for M. Rectus femoris at 150W (p=0,008) was found. The affected leg of patients showed a delayed onset of 80,1° +/- 29,19° in comparison to controls (table 4 and 5, figure 2).

No significant results were found comparing patients to controls or the affected leg to the non-affected leg.

Observing the effect of power level, a significant difference was found for M. Biceps femoris (p<0,001) (table 6).

M. Biceps femoris showed a significant earlier onset for higher power levels when comparing 50W to 125W (p=0,002), 50W to 150W (p<0,001), 75W to 150W (p=0,017) and 100W to 150W (p=0,047) of respectively 28,3° +/- 7,47° at 125W, 36,5° +/- 8,20° at 150W, 26,2° +/- 8,23° at 150W and 24,0° +/- 8,38° at 150W (table 7 and 8, figure 3).

Offset

No overall effect was found for the interaction between power level and group.

Comparing the affected leg of patients to controls or to their non-affected leg, no significant results were observed.

Observing the effect of power level, an overall significant difference was found for M. Rectus femoris (p=0,007), M. Biceps femoris (p<0,001) and M. Semitendinosus (p<0,001) (table 9).
M. Rectus femoris showed a significant delayed offset for higher power levels when comparing 50W to 100W (p=0,018) and 50W to 150W (p=0,021), of respectively 13,8° +/- 4,33° at 100W and 14,9° +/- 4,77° at 150W.
A significant delayed offset of 24,3° +/- 6,10° at 150W was found for M. Biceps femoris when comparing 75W to 150W (p=0,001).
Significant delayed offsets were found for higher power levels for M. Semitendinosus, when comparing 50W to 125W (p=0,001), 100W to 125W (p=0,028) and 100W to 150W (p<0,001) of respectively 35,2° +/- 8,94° at 125W, 27,7° +/- 9,13° at 125W and 27,7° +/- 9,13° at 150W (table 10 and 11, figure 4).

Duration

No overall significant effects were found for the effect of group*power level interaction.

No significant result in duration was observed when comparing patients to controls or the patients' affected leg to the non-affected leg.

Significant results were found for the power level effect for M. Rectus femoris (p<0,001), M. Vastus lateralis obliquus (p<0,001), M. Biceps femoris (p<0,001) and M. Semitendinosus (p<0,001) (table 12).
M. Rectus femoris showed a significant longer duration for higher power levels when comparing 50W to 100W (p=0,024), 50W to 125W (p=0,05), 50W tot 150W (p<0,001) and 75W to 150W (p=0,001), with a difference of respectively 17,64°+/-5,26° at 100W, 20,35°+/-5,75° at 125W, 31,20° +/-6,37° at 150W and 24,83°+/-6,31° at 150W.
For M. Vastus lateralis obliquus, significant longer durations were found for higher power levels when comparing 50W to 100W (p=0,003), 50W to 125W (p=0,005) and 50W to 150W (p=0,011),

with a difference of respectively 12,24° +/-3,34° at 100W, 11,99° +/-3,72° at 125W and 12,15° +/-3,65° at 150W.

Moreover, significant longer durations for higher power levels were observed for M. Biceps femoris comparing 50W to 100W (p<0,001), 50W to 125W (p<0,001), 50W to 150W (p<0,001), 75W to 125W (p<0,001) and 75W to 150W (p<0,001) of respectively 35,96°+/-7,25° at 100W, 51,14° +/-7,32° at 125W, 66,14° +/-8,05° at 150W, 32,33° +/-7,32° at 125W and 47,33° +/-8,04° at 150W.

Finally M. Semitendinosus also showed significant longer durations for higher power levels comparing 50W to 125W (p<0,001), 50W to 150W (p<0,001), 75W to 125W (p=0,012), 75W to 150W (p<0,001) and 100W to 150W (p<0,001) of respectively 40,31°+/-8,17° at 125W, 58,29° +/-8,96° at 150W, 26,61° +/-8,08° at 125W, 44,59° +/-8,89° at 150W and 39,91° +/-9,07° at 150W (table 13 and 14, figure 5).

Peak value

No overall significant result was observed for group*power level interaction.

No significant results for peak value were found when comparing the affected leg of patients to controls or to their non-affected leg.

A significant power level effect on the peak value was found for M. Rectus femoris (p<0,001), M. Vastus lateralis obliquus (p<0,001), M. Vastus medialis obliquus (p<0,001), M. Biceps femoris (p<0,001) and M. Semitendinosus (p<0,001) (table 15).

M. Rectus femoris showed a significant higher peak value for higher power levels when comparing 50W to 100W (p<0,001), 50W to 125W (p<0,001), 50W to 150W (p<0,001), 75W to 125W (p<0,001), 75W to 150W (p<0,001), 100W to 150W (p<0,001) with a difference of respectively 22,2% +/- 5,16% at 100W, 40,7% +/- 5,18% at 125W, 55,6% +/- 5,57% at 150W, 26,9% +/- 5,19% at 125W, 41,9% +/-5,57% at 150W and 33,4% +/- 5,65% at 150W.

Moreover, M. Vastus lateralis showed a significant higher peak value for higher power levels when comparing 50W to 100W (p<0,001), 50W to 125W (p<0,001), 50W to 150W (p<0,001), 75W to 100W (p=0,030), 75W to 125W (p=0,037), 75W to 150W (p=0,003), with a difference of respectively 70,5% +/- 13,84% at 100W, 69,5% +/- 13,86% at 125W, 83,0%+/- 14,64% at 150W, 42,0% +/-13,88% at 100W, 41,0% +/-13,89% at 125W and 54,5% +/-14,67% at 150W.

Furthermore, significant higher peak values were observed for increased power levels for M. Vastus medialis obliquus (p<0,001) comparing 50W to 75W, 50W to 100W, 50W to 125W, 50W to 150W, 75W to 125W, 75W to 150W, 100W to 125W (p=0,024), 100W to 150W and with a difference of

respectively 47,0% +/- 9,41% at 75W, 61,3% +/- 9,88% at 100W, 92,5% +/- 9,89% at 125W, 118,4% +/- 10,56% at 150W, 45,5% +/- 9,83% at 125W, 71,4% +/- 10,49% at 150W, 31,3% +/-10,11% at 125W and 57,2% +/-10,77%.

Additionally, M. Biceps femoris showed significant higher peak values for higher power levels when comparing 50W to 100W(p=0,001), 50W to 125W (p<0,001), 50W to 150W (p<0,001), 75W to 125W (p=0,002), 75W to 150W (p<0,001) and 100W to 150W (p=0,038) with a difference of respectively 18,3% +/- 4,61% at 100W, 25,3% +/- 4,61% at 125W, 33,3% +/- 4,96% at 150W, 17,8% +/- 4,62% at 125W, 25,9% +/- 4,97% at 150W and 15,0% +/- 5,09%.

Lastly M. Semitendinosus, significant higher peak values for increased power levels were found when comparing 50W to 100W (p=0,013), 50W to 125W (p<0,001), 50W to 150W (p<0,001), 75W to 150W (p<0,001), 100W to 150W (p<0,001) with a difference of respectively 11,0% +/- 3,35% at 100W, 16,3% +/- 3,39% at 125W, 26,4% +/- 3,75% at 150W, 18,9% +/- 3,65% at 150W and 15,3% +/- 3,74% at 150W (table 16 and 17, figure 6).

Timing of peak value

M. Vastus Lateralis obliquus showed a significant overall effect for the interaction between group and power level (p=0,014) (table 18).

A significant delayed peak value for patients was found at 50W (p=0,025) with a difference of 30,83° +/- 13,66° compared to the non-affected leg and a delayed peak value of 41,52° +/- 16,65° for patients compared to the control group (p=0,014). At 150W (p=0,018) a significant earlier peak value of 43,32° +/- 18,15° was found for the patients' affected leg compared to the non-affected leg (table 19 and 20, figure 7).

No significant difference was found for the group or power level effect.

Isokinetic muscle strength

Muscle strength of M. Quadriceps and hamstrings measured on the Biodex, were significantly different between the affected leg of patients and controls (p<0,001), patients were 4,7% +/- 1,92% weaker in M. Quadriceps and 9,3% +/- 1,13% in hamstrings. (table 21, figure 8)

DISCUSSION

This study compared muscle activity patterns in patients following TKA to the non-operated limb of the same person and to a healthy control group.

In this research, a mean muscle activity of M. Rectus femoris was observed from 11,7° until 150,8° for the affected leg of patients, from -4,2° until 147,9° for the non-affected leg and from 30,8° until 143,7° for controls. In literature, earlier onset and offset was observed for healthy people. An onset at 286° and an offset at 34° were suggested in the study of Da Silva et al. (2016)[18]. In the study of Enders et al. (2013)[42], onset of M. Rectus femoris starts just before TDC and offset ends at 90°. Dorel et al. (2008)[43] found an onset and offset of respectively -90°and 90°, while Jorge and Hull et al. (1986)[44] found an onset just before TDC and offset of approximately 120°-130°. These last results appear to be corresponding most to the results found in this study, in particular for the control group. However, no significant group difference was found during this study. In conclusion, both the onset and offset of M. Rectus femoris in healthy people observed in literature occur earlier. A mean onset and offset of M. Biceps femoris was observed at 75,8°-256,1° for patients' affected leg, 77,4°-262,7° for the non-affected leg and 83,0°-250,5° for controls. Additionally, a mean onset and offset of M. Semitendinosus was observed at 106°-249,9° for patients' affected leg, 86,5°-244,3° for the non-affected leg and 82,1-237,6° for controls. These findings do not correspond to results reported in literature.

Results regarding hamstrings are controversial. Dorel et al. (2008)[43] found an initiation of the muscle activity of hamstrings just after TDC until BDC, while Jorge and Hull et al. (1986)[44] observed a longer duration of muscle activity, beginning at TDC until 270°. In the study of Ryan and Gregor et al. (1992)[45], M. Biceps femoris and M. Semitendinosus showed activity during the complete pedaling cycle, with a peak activation at 145° and minimum activation at 270°. Da Silva et al. (2016) [18], observed an initiation of M. Semitendinosus at 104° and ending at 190°. The activity of the long head and short head of M. Biceps femoris were independently measured. The long head showed an onset at 54° and offset at 134°, while the onset and the offset of the short head took place later in the crank cycle, respectively at 97° and at 225°. It is important to acknowledge that the population of this last study was rather small, consisting of only nine participants.

A possible explanation for the different results of M. Rectus femoris, M. Biceps femoris and M. Semitendinosus could be a greater variability of muscle activity of bi-articular muscles. The study of Ryan and Gregor et al. (1992)[45], compared muscle activity of mono-articular to bi-articular muscles. The authors concluded that mono-articular muscles (M. gluteus maximus, M. Vastus lateralis obliquus, M. Vastus medialis obliquus, M. Tibialis anterior and M. Soleus) had a small variability in

muscle activity and fulfilled a primary role as power producers. Whereas, bi-articular muscles (M. Biceps femoris, M. Semitendinosus, M. Semimembranosus, M. Rectus femoris, M. Gastrocnemius medialis and M. Gastrocnemius lateralis) showed greater muscle activity variability.[19, 45] Besides this explanation, other interpretations for the different results are plausible. This research tested a rather low number of participants, which can result in higher variability. On the other hand, there is a discrepancy regarding the study population. People following TKA were enrolled in this research, while other studies examined healthy people and athletes, possibly resulting in different muscle activity. Accordingly, more research is necessary in people following TKA.

Significant higher peak values were observed at higher power levels for M. Rectus femoris, M. Vastus medialis obliquus, M. Vastus lateralis obliquus, M. Biceps femoris and M. Semitendinosus. Previous studies noticed this power level effect as well. Ericson M. (1986)[46] reported increased EMG activity of M. Gluteus maximus, M. Rectus femoris, M. Vastus lateralis obliquus, M. Vastus medialis obliquus, M. Biceps femoris, M. Semitendinosus and M. Gastrocnemius when increasing the power level from 120W to 240W, at 60 rpm. Sarre et al. (2002)[47] found significant higher peak values for higher intensities for M. Vastus medialis obliquus, M. Vastus lateralis obliquus and M. Rectus femoris. The participants cycled at three intensities, respectively 60%, 80% and 100% of their maximal aerobic power (MAP), which was individually determined.

The influence of power level on muscle activation timing is not studied well. The review of Hug. Et al (2009)[19] included only one article[44] relating to this topic. Jorge and Hull (1986)[44] concluded that muscle activity patterns are not strongly influenced by the power level. Further research about this topic is necessary.

In this study, a significant delayed peak value for M. Vastus lateralis obliquus of the patients' affected leg was found at 50W compared to the non-affected leg and control group and at 150W compared to the non-affected leg. Mean timing of peak value of M. Vastus lateralis obliquus in the affected and non-affected leg were respectively 97,6° and 92,1°. Moreover, mean timing of peak value of M. Vastus medialis obliquus in the affected and non-affected leg were respectively 91,2° and 91,8° in accordance with Q2 in the crank cycle.
The timing of peak value of M. Vastus lateralis obliquus and M. Vastus medialis obliquus in healthy cyclists is studied in the research of Da Silva et al. (2016)[18] with similar results. Mean timing of peak value of both vastii was seen during Q1, which is different compared to this study. However, a greater activation was found in Q2 compared to Q3.

The mean timing of peak value for M. Rectus femoris of the patients' affected leg, non-affected leg and controls were respectively 85,7°; 82,8° and 66,2° corresponding to Q1. This correlates with six out of nine subjects of the study of Da Silva et al. (2016)[18]. These six participants had continuous EMG burst between Q4 and Q1. M Rectus femoris of the other three subjects showed two distinct activation bursts in Q4 and Q1 with no significant difference between them. An activation pattern with two separate EMG-burst was observed in this research as well for some patients and controls. However, the highest peak value was located in Q1, therefore the timing of this peak value was used for data analysis.

This research observed no significant effects between patients following TKA and healthy controls. During other activities, such as walking, significant group differences were found in literature. Kuntze G. et al. (2015)[14] described a delayed onset after heel strike and a prolonged muscle activation at mid stance for M. Vastus medialis obliquus and M. Biceps femoris. Yoshida Y. et al. (2013)[16] found a significant lower muscle recruitment in M. Quadriceps of the affected leg during loading response three months following TKA compared to the non-affected leg and healthy controls. This gait analysis showed no differences in muscle recruitment patterns in the co-contraction of M. Quadriceps and hamstrings. The weakness of the M. Quadriceps is related to the deficits in voluntary muscle activation and muscle atrophy. This research suggests retraining muscle recruitment patterns to increase relative M. Quadriceps recruitment and lessen the recruitment from the hamstring muscles during gait.

Significantly lower muscle strength of the patients' affected leg was observed for M. Quadriceps and hamstrings compared to controls. Countless studies investigated the strength of M. Quadriceps. Persistent weakness of M. Quadriceps has been demonstrated for over two years after TKA.[27] A couple of studies researched the strength of the hamstrings, but no conclusion could be made.[28] Some studies suggest the hamstrings strength recovers faster than the strength of M. Quadriceps.[29, 30] Other studies suggest hamstrings and M. Quadriceps strength recover at the same rate.[30, 31] Therefore, the significant results of the weaker M. Quadriceps and hamstrings strength in patients' affected leg can be explained.

No studies about muscle activity during cycling in patients with TKA were found in literature. The population of this study is too small to make any distinct conclusions. As a result, more research concerning EMG activity in patients after TKA is needed.

Limitations

Testing results from a previous study of Ghyselinck R. and Ghillebert S. (2016) were included in this study, resulting in a few limitations. During MVC, muscle strength of M. Quadriceps and hamstrings was measured against manual resistance. Therefore, decreased reliability can occur due to the manual resistance being fulfilled by two different researchers and the use of three different EMG systems, Noraxon Myosystem 1400A, Telemyo system 2400t G2 and Noraxon DTS system.
The study of Ghyselinck R. and Ghillebert S. (2016) did not describe everything in detail. As consequence, the reproducibility was not perfect resulting in misinterpretation. During MVC, it is required to perform three trials to obtain a reliable value for determining the baseline. In the previous study only one MVC trial was performed, resulting in a lower reliability.

During testing of the participants, certain problems with EMG signals arose. Several EMG signals are not accurately measured, due to noise on the signal during measuring. A few signals could not be recorded. Therefore, certain signals were enrolled as missing values.
Another reason for the input of missing values can be as a result of data analysis. During autotracking of the knee angle, the skinmarker on the ankle joint could not always be found by the Noraxon Myoresearch software. Thus, recruitment patterns of four measurements could not be analyzed.

For determining the baseline, 10% of MVC was used. For some subjects, this baseline was too low, therefore some muscles were never active. In the latter cases, the activity level was determined visually by observing the graphs.

A few participants did not perform the MVC at their maximum capacity. Consequently, in some cases the relative maximum of the peak value was higher than 100%.

Some limitations of the previous research are still of importance for this study. Two of the included patients had a TKA bilaterally. The surgery of the contralateral side was performed over five years before the testing moment. This could result in changed muscle strength or muscle activation, possibly resulting in false-positive or false-negative test results.

Only 10 out of 21 patients and 18 out of 21 controls were able to cycle the full protocol until 150W. This results in a low power level for statistical conclusion strength. Interpretation of these results

had to be done carefully. Due to little study population, there is a possibility of false positive or false negative results.

A control group was recruited matched for sex, age, BMI and leg dominance to the patient population. Nevertheless, average BMI of the control group was lower than BMI of the patient population. Therefore, better physical health of the control group and less subcutaneous fat are present, resulting in better transmission of EMG signals.

It is important to mention that the authors of this study did not ask the patients for information about their rehabilitation protocol. The intensity, duration and specific exercises of rehabilitation can influence the muscle activity, leading to more insights regarding the results.

CONCLUSION

Significant results for the interaction between power level and group were found.

No significant differences were found when comparing the affected leg of patients to the non-affected leg or to controls, regardless of the power level. Significant results of the power level were found. An earlier onset and later offset with increasing power levels were observed, resulting in a longer duration. Significant higher peak values for higher power levels were found as well.

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ABSTRACT LEKENTAAL

Achtergrond Er worden telkens meer operaties van totale knieprothesen uitgevoerd en dit heeft in een belangrijke impact op de activiteiten uit het dagelijkse leven, zoals fietsen. Evaluatie van het spiergebruik in deze patiënten kan verdere informatie geven, waardoor revalidatieprotocols aangepast kunnen worden.

Doelstellingen De spieractiviteit bij patiënten met een totale knieprothese vergelijken met het niet-aangedane lidmaat van dezelfde persoon en met een gezonde controlegroep.

Type onderzoek Patiënten vergelijken met gezonde personen

Methode 21 patiënten, ongeveer 1 jaar na de operatie, en 21 gematchte controlepersonen namen deel aan deze studie. Deelnemers voltooiden drie testen: een maximale krachttest tegen weerstand van de therapeut, een krachttest tegen weerstand van een toestel, waarbij de knie met een vaste snelheid gestrekt en geplooid moest worden en een fietstest op een hometrainer. De fietstest bestond uit verschillende niveaus van toenemende weerstanden, nl. 50, 75, 100, 125, 150 Watt (W) aan 80-85 rotaties per minuut. Er werd één minuut actieve recuperatie aan 50W tussen twee niveaus gegeven. Elk niveau werd 20 seconden aangehouden, waarbij de gegevens werden opgeslagen. De spiergebruik van de bovenbeenspieren werd tijdens de drie testen geregistreerd bij patiënten en bij de controlegroep. Verschillen in de initiatie, einde, duur, timing van de maximale waarde en de maximale waarde van de vijf bovenbeenspieren werden geanalyseerd.

Resultaten Belangrijke resultaten werden gevonden voor het vergelijken van het aangedane en niet-aangedane been van de patiënten, waarbij ook het wattage in rekening gebracht werd. Hierbij was er een later begin van de spieractiviteit bij patiënten op 150W voor M. Rectus femoris. Daarnaast was er op 50W voor M. Vastus lateralis obliquus een latere maximale waarde voor de patiënten vergeleken met hun niet-aangedane zijde en met de controlegroep. Op 150W was er een eerdere maximale waarde voor de aangedane zijde van patiënten in vergelijking met de niet-aangedane zijde. Ook voor het effect van de weerstandsverhoging tijdens de fietsproef werden er duidelijke resultaten waargenomen. Hierbij werd het verschil in groep niet mee in rekening gebracht. M. Biceps femoris werd eerder actief bij een hogere weerstand, terwijl activiteit van de M. Rectus femoris, M. Biceps femoris en M. Semitendinosus later eindigden bij een hogere weerstand. Vervolgens waren de M. Rectus femoris, M. Vastus lateralis obliquus, M. Biceps femoris en M. Semitendinosus langer actief bij een hogere weerstand. De maximale waarde voor M. Rectus femoris, M. Vastus lateralis obliquus, M. Vastus medialis obliquus, M. Biceps femoris en M. Semitendinosus was tevens hoger bij een hogere weerstand.

Het geopereerde been van de patiënten vertoonde een zwakkere spierkracht van de kniestrekkers en kniebuigers vergeleken met controlepersonen.

Conclusie Belangrijke resultaten werden gevonden voor de vergelijking tussen de verschillende groepen, waarbij de weerstand tijdens het fietsen mee in rekening gebracht werd. Wanneer het aangedane been van patiënten vergeleken werd met het niet-aangedane been of met de controles, ongeacht het weerstandsniveau, werden er geen verschillen gevonden. Vervolgens werd er een vroegere start en later einde tijdens hogere wattages waargenomen, waardoor de spieren langer actief waren. Ten slotte, werden er ook hogere maximale waardes tijdens een hogere weerstanden waargenomen.

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DOCUMENT E (scripties – Z-lijn)

VERZOEK TOT ADVIES VAN HET ETHISCH COMITE BETREFFENDE EEN prospectief observationeel ONDERZOEKSPROJECT OP GEZONDHEIDSGEGEVENS voor het maken van scriptie en Z-lijn als deel van een reeds goedgekeurd akademisch onderzoek
(enkel verzameling van patientengegevens, vragenlijsten en interviews)

Dit document moet maar 1x ingediend worden indien de scriptie of Z-lijn kadert in een eerder goedgekeurde akademische studie van de promotor (staflid UZ Gent of U Gent).

De studenten moeten eerst contact opnemen met Prof.dr. R. Rubens voor verdere inlichtingen *robert.rubens@UGent.be*.

Wanneer de scriptie of Z-lijn niet verbonden is aan een globaal akademisch onderzoek, maar enkel opgezet is voor de scriptiestudent, dan moet de indiening gebeuren via de standaardprocedure (document D)

1. TITEL VAN HET ONDERZOEK :

EVALUATIE VAN DE SPIERACTIVITEIT VAN SPIEREN RONDOM DE KNIE TIJDENS FIETSEN.

2. PROJECTNUMMER (EC), NAAM AANVRAGER VAN HET REEDS INGEDIENDE AKADEMISCH ONDERZOEK + DATUM GOEDKEURING:

- PROJECTNUMMER: EC/2015/0725
- NAAM ONDERZOEKER: DR. NELE ARNOUT
- DATUM GOEDKEURING:28/07/2015 + 13/12/2017 (AMENDEMENT)

3. ONDERZOEK IN FUNCTIE VAN:

☐ BACHELOR SCRIPTIE
- NAAM STUDENT(EN):
- OPLEIDING:
- NAAM HOGESCHOOL:
- EMAIL STUDENT:
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■ MASTERSCRIPTIES OF Z-LIJN
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- VOOROPLEIDING:

- HOOGST BEHAALD DIPLOMA:
- WERKERVARING:

4. SOORT ONDERZOEK

■ VERZAMELEN VAN PATIENTENGEGEVENS, DIE KLINISCH STANDAARD GEGEVEN ZIJN (=GEEN ENKEL AANVULLEND ONDERZOEK, BLOED- OF ANDERE STAALAFNAME)

☐ VRAGENLIJSTEN
☐ INTERVIEW
■ ANDERE: AFNEMEN VAN EEN ISOKINETISCHE TEST EN REGISTREREN SPIERACTIVITEIT TIJDENS HET FIETSEN

5. TAAK VAN DE STUDENT BIJ DIT ONDERZOEK:

CONTACTERENVAN DE PROEFPERSONEN. UITVOEREN VAN DE TESTEN (EMG ANALYSES, ISOKINETISCHE SPIERKRACHTTEST VAN QUADRICEPS EN HAMSTRINGS OP DE BIODEX, FIETSERGOMETER PROEF)

6. GEGEVENS VAN DE PROMOTOR + AFFILIATIE:

- NAAM: PROF. DR. TINE WILLEMS
- FUNCTIE: ZAP
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7. PERIODE VAN HET SCRIPTIE GEDEELTE (BEGIN- EN EINDDATUM MAAND/JAAR)

13/11/2017 – 30/09/2018

IK VERKLAAR DE GEHELE VERANTWOORDELIJKHEID VAN HET HIERBOVEN VERMELD PROJECT OP MIJ TE NEMEN EN BEVESTIG DAT VOOR ZOVER DE HUIDIGE KENNIS HET TOELAAT, DE GEGEVEN INLICHTINGEN MET DE WERKELIJKHEID OVEREENSTEMMEN.

DE HOOFDONDERZOEKER

DATUM : 27/2/18
NAAM : DR. NELE ARNOUT
HANDTEKENING :

HET U.Z. DIENSTHOOFD OF DE VAKGROEPVOORZITTER (VOOR AKKOORD)

DATUM : 16/2/18
NAAM : PROF. DR. PHILIP ROOSEN
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(ZO VERSCHILLEND VAN DE HOOFDONDERZOEKER)

DATUM: 16/2/18
NAAM + AFFILIATIE: PROF. DR. TINE WILLEMS
HANDTEKENING:

NAAM STUDENTEN

DATUM : 13/02/18
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- EMAIL STUDENT:
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■ MASTERSCRIPTIES OF Z-LIJN
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☐ INDIEN WERKSTUDENT:
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DE HOOFDONDERZOEKER

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NAAM : DR. NELE ARNOUT
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(ZO VERSCHILLEND VAN DE HOOFDONDERZOEKER)

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NAAM STUDENTEN

DATUM : 10/2/2018
NAAM: LORE VAN LOON
HANDTEKENING: Van Loon

APPENDIX

Tables

Onset

		RF		VLO		VMO		BF		ST	
Main effect		0,002*		0,064		0,912		0,749		0,407	
Power level	**Group**	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error
50W	Affected leg patients	22,1	19,13	18,3	12,41	4,7	10,67	88,8	17,73	113,1	17,91
	Non-affected leg patients	6,7	18,44	14,7	12,02	5,7	10,45	86,1	17,09	89,2	18,90
	Controls	26,4	17,72	-6,6	11,67	9,6	10,13	105,6	17,32	71,4	17,36
75W	Affected leg patients	28,4	19,42	12,9	12,64	4,9	10,92	80,6	18,15	108,2	18,18
	Non-affected leg patients	-2,9	18,51	10,9	12,63	5,9	11,17	79,5	17,60	81,6	18,66
	Controls	5,7	17,72	29,5	11,67	10,7	10,13	90,0	17,32	89,3	17,36
100W	Affected leg patients	10,9	19,32	16,8	13,36	5,3	11,72	88,2	18,55	109,1	18,65
	Non-affected leg patients	-0,6	18,90	8,5	12,60	1,9	11,14	75,9	17,76	90,7	19,19
	Controls	32,3	18,04	-8,9	12,02	-3,1	10,57	81,2	17,62	84,1	17,78
125W	Affected leg patients	-1,6	19,63	4,4	13,36	19,0	11,72	55,6	18,55	88,0	18,95
	Non-affected leg patients	-14,5	18,90	6,2	12,84	-0,9	11,43	68,2	17,96	82,0	19,19
	Controls	31,0	18,04	15,5	12,02	-2,0	10,57	72,1	17,62	98,3	17,78
150W	Affected leg patients	-16,4	21,85	22,8	14,89	4,9	13,921	46,7	20,21	107,4	21,18
	Non-affected leg patients	-19,6	20,52	6,9	14,45	-3,1	13,39	68,7	19,40	90,5	21,40
	Controls	63,7	18,23	-10,7	12,24	-8,6	10,83	58,7	17,80	66,6	18,03

Table 3: Group and power level interaction on onset
All values are expressed as °.
* The mean difference is significant at the <0,05 level

	RF		VLO		VMO		BF		ST	
Group 1	Affected leg patients		Affected leg patients		Affected leg patients		Affected leg patients		Affected leg patients	
Group 2	Non-affected leg patients	controls	Non-affected leg patients	controls	Non-affected leg patients	controls	Non-affected leg patients	controls	Non-affected leg patients	Controls
50W	0,359	0,874	0,767	0,157	0,936	0,740	0,869	0,512	0,187	0,108
75W	0,069	0,407	0,876	0,349	0,943	0,754	0,947	0,716	0,138	0,464
100W	0,509	0,433	0,544	0,334	0,810	0,752	0,500	0,789	0,331	0,346
125W	0,465	0,240	0,896	0,550	0,168	0,192	0,491	0,529	0,782	0,561
150W	0,883	0,008*	0,336	0,092	0,648	0,449	0,302	0,663	0,470	0,153

Table 4: Significant effects for group and power level interaction on onset

* The mean difference is significant at the <0,05 level.

			RF		VLO		VMO		BF		ST	
Power level	Group (I)	Group (J)	Mean difference (I-J)	Std. Error	Mean difference (I-J)	Std. Error	Mean difference (I-J)	Std. Error	Mean difference (I-J)	Std. Error	Mean difference (I-J)	Std. Error
50W	Affected leg patients	Non-affected	15,4	16,69	3,7	12,41	-1,0	12,86	2,7	16,52	23,9	17,93
		Controls	-4,3	26,86	25,0	17,46	-5,0	14,91	-16,8	25,41	41,7	25,56
75W	Affected leg patients	Non-affected	31,3	16,90	2,0	12,94	-1,0	13,52	1,2	17,39	26,7	17,75
		Controls	22,7	27,10	-16,6	17,63	-5,8	15,12	-9,4	25,72	19,0	25,76
100W	Affected leg patients	Non-affected	11,5	17,31	8,3	13,65	3,4	14,19	12,3	18,10	18,4	18,83
		Controls	-21,5	27,18	25,6	18,35	8,3	15,96	7,0	26,18	25,0	26,33
125W	Affected leg patients	Non-affected	13,0	17,67	-1,8	13,81	19,9	14,37	-12,6	18,24	5,3	19,14
		Controls	-32,6	27,43	-11,0	18,37	20,9	15,98	-16,6	26,20	-10,3	26,56
150W	Affected leg patients	Non-affected	3,2	21,64	15,9	16,46	8,0	17,49	-22,1	21,28	16,9	23,35
		Controls	-80,1	29,19	33,4	19,6	13,5	17,80	-12,0	27,52	40,9	28,33

Table 5: Mean difference for group and power level interaction on onset
All values are expressed as °.

	RF		VLO		VMO		BF		ST	
Main effect	0,511		0,278		0,675		<0,001*		0,908	
	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error
50W	20,7	11,96	7,2	7,43	6,5	6,23	94,6	10,98	89,3	11,31
75W	11,4	12,00	17,8	7,59	7,0	6,39	84,4	11,10	91,8	11,34
100W	19,2	12,16	3,3	7,78	0,6	6,61	82,2	11,25	93,1	11,60
125W	10,0	12,19	8,4	7,83	4,2	6,66	66,3	11,28	89,3	11,64
150W	23,3	12,74	2,1	8,35	-3,9	7,34	58,2	11,73	83,5	12,30

Table 6: Power level effect on onset

All values are expressed as °.

* The mean difference is significant at the <0,05 level

		RF	VLO	VMO	BF	ST
Power level	Power level	Sign.	Sign.	Sign.	Sign.	Sign.
50W	75W	1,000	1,000	1,000	1,000	1,000
	100W	1,000	1,000	1,000	0,940	1,000
	125W	1,000	1,000	1,000	0,002*	1,000
	150W	1,000	1,000	1,000	<0,001*	1,000
75W	100W	1,000	0,571	1,000	1,000	1,000
	125W	1,000	1,000	1,000	0,171	1,000
	150W	1,000	0,578	1,000	0,017*	1,000
100W	125W	1,000	1,000	1,000	0,400	1,000
	150W	1,000	1,000	1,000	0,047*	1,000
125W	150W	1,000	1,000	1,000	1,000	1,000

Table 7: Significant effects for power level effect on onset

* The mean difference is significant at the <0,05 level

		RF		VLO		VMO		BF		ST	
Power level (I)	Power level (J)	Mean difference (I-J)	Std. Error	Mean difference (I-J)	Std. Error	Mean difference (I-J)	Std. Error	Mean difference (I-J)	Std. Error	Mean difference (I-J)	Std. Error
50W	75W	9,3	8,53	-10,6	7,20	-0,5	7,36	10,2	7,14	-2,4	8,70
	100W	1,5	8,86	3,9	7,45	6,0	7,59	12,5	7,40	-3,8	9,08
	125W	10,7	8,89	-1,2	7,52	2,3	7,66	28,3	7,47	0,1	9,15
	150W	-2,6	9,75	5,1	8,12	10,4	8,33	36,5	8,20	5,8	10,04
75W	100W	-7,8	8,77	14,4	7,54	6,4	7,67	2,2	7,47	-1,3	9,04
	125W	1,4	8,81	9,4	7,59	2,8	7,72	18,1	7,50	2,5	9,11
	150W	-11,9	9,66	15,6	8,20	10,9	8,39	26,2	8,23	8,3	10,02
100W	125W	9,2	8,93	-5,1	7,72	-3,6	7,86	15,8	7,66	3,8	9,33
	150W	-4,1	9,77	1,2	8,31	4,4	8,51	24,0	8,38	9,6	10,23
125W	150W	13,3	9,74	6,3	8,30	8,1	8,50	8,2	8,35	5,8	10,21

Table 8: Mean difference for power level effect on onset
All values are expressed as °.

Offset

	RF		VLO		VMO		BF		ST	
Main effect	0,007*		0,068		0,266		<0,001*		<0,001*	
	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error
50W	137,6	5,82	154,6	5,68	158,4	5,93	238,5	8,19	223,6	8,29
75W	145,5	5,83	156,7	5,75	160,4	6,00	249,2	8,28	235,6	8,32
100W	151,3	5,91	165,4	5,84	167,7	6,10	262,1	8,38	231,0	8,65
125W	149,7	5,93	163,3	5,85	163,8	6,12	264,7	8,41	258,8	8,70
150W	152,5	6,20	159,1	6,08	158,8	6,40	273,5	8,74	276,7	9,52

Table 9: Power level effect on offset
All values are expressed as °.
* The mean difference is significant at the <0,05 level

		RF	VLO	VMO	BF	ST
Power level	Power level	Sign.	Sign.	Sign.	Sign.	Sign.
50W	75W	0,602	1,000	1,000	0,462	1,000
	100W	0,018*	0,110	0,474	<0,001*	1,000
	125W	0,060	0,414	1,000	<0,001*	0,001*
	150W	0,021*	1,000	1,000	<0,001*	<0,001*
75W	100W	1,000	0,418	0,418	0,203	1,000
	125W	1,000	1,000	1,000	0,059	0,103
	150W	1,000	1,000	1,000	0,001*	<0,001*
100W	125W	1,000	1,000	1,000	1,000	0,028*
	150W	1,000	1,000	0,886	0,693	<0,001*
125W	150W	1,000	1,000	1,000	1,000	0,746

Table 10: Significant effects for power level effect on offset

* The mean difference is significant at the <0,05 level

		RF		VLO		VMO		BF		ST	
Power level (I)	Power level (J)	Mean difference (I-J)	Std. Error	Mean difference (I-J)	Std. Error	Mean difference (I-J)	Std. Error	Mean difference (I-J)	Std. Error	Mean difference (I-J)	Std. Error
50W	75W	-7,9	4,17	-2,1	4,06	-2,0	4,48	-10,6	5,30	-12,1	8,52
	100W	-13,8	4,33	-10,8	4,20	-9,2	4,63	-23,6	5,49	-7,5	8,88
	125W	-12,1	4,35	-8,7	4,24	-5,4	4,68	-26,1	5,54	-35,2	8,94
	150W	-14,9	4,77	-4,5	4,58	-0,4	5,09	-35,0	6,08	-53,1	9,81
75W	100W	-5,9	4,29	-8,7	4,26	-7,3	4,67	-13,0	5,54	4,6	8,85
	125W	-4,2	4,31	-6,6	4,28	-3,4	4,70	-15,5	5,57	-23,1	8,91
	150W	-7,0	4,72	-2,4	4,62	1,6	5,11	-24,3	6,10	-41,0	9,80
100W	125W	1,6	4,37	2,1	4,35	3,9	4,77	-2,5	5,68	-27,7	9,13
	150W	-1,2	4,78	6,3	4,69	8,9	5,18	-11,4	6,22	-45,6	10,01
125W	150W	2,8	4,76	4,2	4,67	5,0	5,16	-8,8	6,19	-17,9	9,99

Table 11: Mean difference for power level effect on offset
All values are expressed as °.

Duration

	RF		VLO		VMO		BF		ST	
Main effect	<0,001*		<0,001*		0,128		<0,001*		<0,001*	
	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error
50W	148,5	6,74	154,8	3,31	160,6	4,15	146,6	8,85	135,3	10,86
75W	154,8	6,76	158,1	3,38	162,4	4,23	165,4	8,96	149,0	10,84
100W	166,1	6,87	167,1	3,47	168,7	4,33	182,6	9,13	153,7	11,06
125W	168,8	6,89	166,8	3,49	168,3	4,36	197,8	9,17	175,6	11,09
150W	179,7	7,32	167,0	3,73	169,6	4,68	212,8	9,71	193,6	11,64

Table 12: Power level effect on duration
All values are expressed as °.
* The mean difference is significant at the <0,05 level

		RF	VLO	VMO	BF	ST
Power level	Power level	Sign.	Sign.	Sign.	Sign.	Sign.
50W	75W	1,000	1,000	1,000	0,078	0,793
	100W	0,024*	0,003*	0,528	<0,001*	0,246
	125W	0,005*	0,005*	0,666	<0,001*	<0,001*
	150W	<0,001*	0,011*	0,487	<0,001*	<0,001*
75W	100W	0,488	0,091	1,000	0,196	1,000
	125W	0,151	0,116	1,000	<0,001*	0,012*
	150W	0,001*	0,173	1,000	<0,001*	<0,001*
100W	125W	1,000	1,000	1,000	0,437	0,087
	150W	0,353	1,000	1,000	0,003	<0,001*
125W	150W	0,898	1,000	1,000	0,678	0,484

Table 13: Significant effects for power level effect on duration

* The mean difference is significant at the <0,05 level

		RF		VLO		VMO		BF		ST	
Power level (I)	Power level (J)	Mean difference (I-J)	Std. Error	Mean difference (I-J)	Std. Error	Mean difference (I-J)	Std. Error	Mean difference (I-J)	Std. Error	Mean difference (I-J)	Std. Error
50W	75W	-6,4	5,51	-3,3	3,23	-1,8	3,98	-18,8	6,99	-13,7	7,76
	100W	-17,6	5,73	-12,2	3,34	-8,0	4,11	-36,0	7,25	-18,4	8,10
	125W	-20,4	5,75	-12,0	3,37	-7,6	4,15	-51,1	7,32	-40,3	8,17
	150W	-31,2	6,37	-12,2	3,65	-9,0	4,52	-66,1	8,05	-58,3	8,96
75W	100W	-11,3	5,68	-8,9	3,39	-6,2	4,16	-17,2	7,28	-4,7	8,01
	125W	-14,0	5,69	-8,7	3,41	-5,8	4,18	-32,3	7,32	-26,6	8,08
	150W	-24,8	6,31	-8,8	3,69	-7,2	4,55	-47,3	8,04	-44,6	8,89
100W	125W	-2,7	5,78	0,3	3,47	0,4	4,25	-15,2	7,47	-21,9	8,27
	150W	-13,6	6,39	0,1	3,74	-1,0	4,61	-30,2	8,20	-39,9	9,07
125W	150W	-10,8	6,36	-0,2	3,73	-1,3	4,60	-15,0	8,16	-18,0	9,05

Table 14: Mean difference for power level effect on duration
All values are expressed as °.

Peak value

	RF		VLO		VMO		BF		ST	
Main effect	<0,001		<0,001		<0,001		<0,001		<0,001	
	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error
50W	40,2	6,44	85,3	12,91	102,6	14,54	50,4	7,21	49,1	7,06
75W	54,0	6,47	113,8	13,01	149,6	14,59	57,9	7,26	56,6	7,08
100W	62,4	6,53	155,8	13,59	163,9	14,85	68,7	7,37	60,1	7,14
125W	80,9	6,57	154,8	13,58	195,1	14,84	75,7	7,36	65,4	7,15
150W	95,9	6,85	168,3	14,32	221,0	15,25	83,7	7,57	75,5	7,27

Table 15: Power level effect on peak value

All values are expressed as % of their MVC.

* The mean difference is significant at the <0,05 level

		RF	VLO	VMO	BF	ST
Power level	Power level	Sign.	Sign.	Sign.	Sign.	Sign.
50W	75W	0,068	0,327	<0,001*	0,946	0,221
	100W	<0,001*	<0,001*	<0,001*	0,001*	0,013*
	125W	<0,001*	<0,001*	<0,001*	<0,001*	<0,001*
	150W	<0,001*	<0,001*	<0,001*	<0,001*	<0,001*
75W	100W	1,000	0,030*	1,000	0,205	1,000
	125W	<0,001*	0,037*	<0,001*	0,002*	0,106
	150W	<0,001*	0,003*	<0,001*	<0,001*	<0,001*
100W	125W	0,006*	1,000	0,024*	1,000	1,000
	150W	<0,001*	1,000	<0,001*	0,038*	0,001*
125W	150W	0,087	1,000	0,165	1,000	0,074

Table 16: Significant effects for power level effect on peak value

* The mean difference is significant at the <0,05 level

		RF		VLO		VMO		BF		ST	
Power level (I)	Power level (J)	Mean difference (I-J)	Std. Error	Mean difference (I-J)	Std. Error	Mean difference (I-J)	Std. Error	Mean difference (I-J)	Std. Error	Mean difference (I-J)	Std. Error
50W	75W	-13,7	4,99	-28,5	13,20	-47,0	9,41	-7,4	4,42	-7,5	3,22
	100W	-22,2	5,16	-70,5	13,84	-61,3	9,88	-18,3	4,61	-11,0	3,35
	125W	-40,7	5,18	-69,5	13,86	-92,5	9,89	-25,3	4,61	-16,3	3,39
	150W	-55,6	5,57	-83,0	14,64	-118,4	10,56	-33,3	4,96	-26,4	3,65
75W	100W	-8,5	5,17	-42,0	13,88	-14,3	9,82	-10,8	4,62	-3,6	3,35
	125W	-26,9	5,19	-41,0	13,89	-45,5	9,83	-17,8	4,62	-8,8	3,39
	150W	-41,9	5,57	-54,5	14,67	-71,4	10,49	-25,9	4,97	-18,9	3,65
100W	125W	-18,5	5,27	1,0	14,32	-31,3	10,11	-7,0	4,75	-5,2	3,48
	150W	-33,4	5,65	-12,5	15,08	-57,2	10,77	-15,0	5,09	-15,3	3,74
125W	150W	-15,0	5,61	-13,5	14,96	-25,9	10,67	-8,0	5,04	-10,1	3,72

Table 17: Mean difference for power level effect on peak value
All values are expressed as % of their MVC.

Timing of peak value

		RF		VLO		VMO		BF		ST	
Main effect		0,353		0,014*		0,636		0,479		0,383	
Power level	**Group**	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error
50W	Affected leg patients	68,0	12,75	114,3	11,95	96,4	10,75	156,5	15,25	173,8	13,93
	Non-affected leg patients	88,2	12,09	83,5	11,47	87,9	10,64	163,4	14,68	156,3	14,57
	Controls	64,9	11,41	72,8	11,14	83,2	10,28	157,7	14,91	150,7	13,50
75W	Affected leg patients	91,3	13,08	100,0	12,22	97,6	10,93	153,1	15,79	177,1	14,13
	Non-affected leg patients	79,8	12,13	90,3	12,18	93,0	11,10	162,3	15,38	160,8	14,39
	Controls	51,6	11,41	83,8	11,14	81,8	10,28	148,6	14,91	155,1	13,50
100W	Affected leg patients	88,9	12,97	100,9	13,08	96,9	11,45	167,0	16,34	170,5	14,47
	Non-affected leg patients	84,7	12,59	94,2	12,15	98,5	11,08	172,7	15,59	162,2	14,78
	Controls	79,6	11,80	116,0	11,56	92,1	10,54	157,8	15,35	179,3	13,81
125W	Affected leg patients	86,2	13,32	92,2	13,08	87,8	11,45	141,0	16,34	165,5	14,69
	Non-affected leg patients	74,4	12,59	92,3	12,43	90,8	11,26	181,2	15,87	155,0	14,78
	Controls	71,4	11,79	82,9	11,55	91,1	10,55	182,6	15,35	171,9	13,81
150W	Affected leg patients	102,5	15,87	64,8	14,89	64,7	12,87	149,2	18,66	187,5	16,34
	Non-affected leg patients	82,2	14,49	108,1	14,34	88,7	12,51	161,7	17,88	153,4	16,43
	Controls	66,4	12,03	68,4	11,80	77,3	10,71	148,0	15,62	168,5	14,00

Table 18: Group and power level interaction on timing of peak value
All values are expressed as °.
* The mean difference is significant at the <0,05 level

	RF		VLO		VMO		BF		ST	
Group 1	Affected leg patients		Affected leg patients		Affected leg patients		Affected leg patients		Affected leg patients	
Group 2	Non-affected leg patients	controls	Non-affected leg patients	controls	Non-affected leg patients	controls	Non-affected leg patients	controls	Non-affected leg patients	Controls
50 W	0,156	0,860	0,025*	0,014*	0,418	0,388	0,648	0,955	0,169	0,252
75 W	0,423	0,027*	0,496	0,338	0,678	0,308	0,572	0,839	0,194	0,277
100 W	0,773	0,601	0,657	0,395	0,890	0,764	0,736	0,689	0,536	0,667
125 W	0,434	0,417	0,993	0,603	0,802	0,839	0,022*	0,072	0,439	0,758
150W	0,279	0,077	0,018*	0,852	0,092	0,463	0,554	0,963	0,045*	0,389

Table 19: Significant effects for group and power level interaction on timing of peak value

* The mean difference is significant at the <0,05 level.

			RF		VLO		VMO		BF		ST	
Power level	Group (I)	Group (J)	Mean difference (I-J)	Std. Error	Mean difference (I-J)	Std. Error	Mean difference (I-J)	Std. Error	Mean difference (I-J)	Std. Error	Mean difference (I-J)	Std. Error
50W	Affected leg patients	Non-affected	-20,2	14,08	30,8	13,66	8,6	10,51	-7,0	15,20	17,5	12,64
		Controls	3,1	17,50	41,5	16,65	13,2	15,24	-1,3	21,77	23,1	19,90
75W	Affected leg patients	Non-affected	11,5	14,29	9,8	14,29	4,6	10,99	-9,2	16,20	16,3	12,48
		Controls	39,7	17,77	16,2	16,85	15,8	15,40	4,5	22,18	22,0	20,04
100W	Affected leg patients	Non-affected	4,2	14,66	6,7	15,07	-1,6	11,54	-5,8	17,07	8,3	13,30
		Controls	9,4	17,88	-15,1	17,72	4,8	15,91	9,2	22,83	-8,8	20,47
125W	Affected leg patients	Non-affected	11,8	14,98	-0,1	15,26	-2,9	11,68	-40,2	17,24	10,5	13,54
		Controls	14,8	18,16	9,2	17,73	-3,2	15,93	-41,6	22,86	-6,4	20,63
150W	Affected leg patients	Non-affected	20,3	18,65	-43,3	18,15	-23,9	14,11	-12,5	21,07	34,1	16,83
		Controls	36,1	20,24	-3,6	19,24	-12,6	17,08	1,2	24,73	19,0	21,95

Table 20: Mean difference for group and power level interaction effect on timing of peak value
All values are expressed as °.

Isokinetic strength

	Affected leg patients		**Non-affected leg patients**		**Controls**		**Sign.**	
	Mean	SD	Mean	SD	Mean	SD	Affected leg patients	
							Control	Non-affected leg patients
M. Quadriceps	68,9	27,29	73,6	36,69	97,8	28,74	<0,001*	0,41
Hamstrings	36,5	23,06	38,1	16,36	45,8	14,21	<0,001*	0,436

Table 21: Group effect on peak torque/body weight
All values are expressed as %.

Figures

Onset

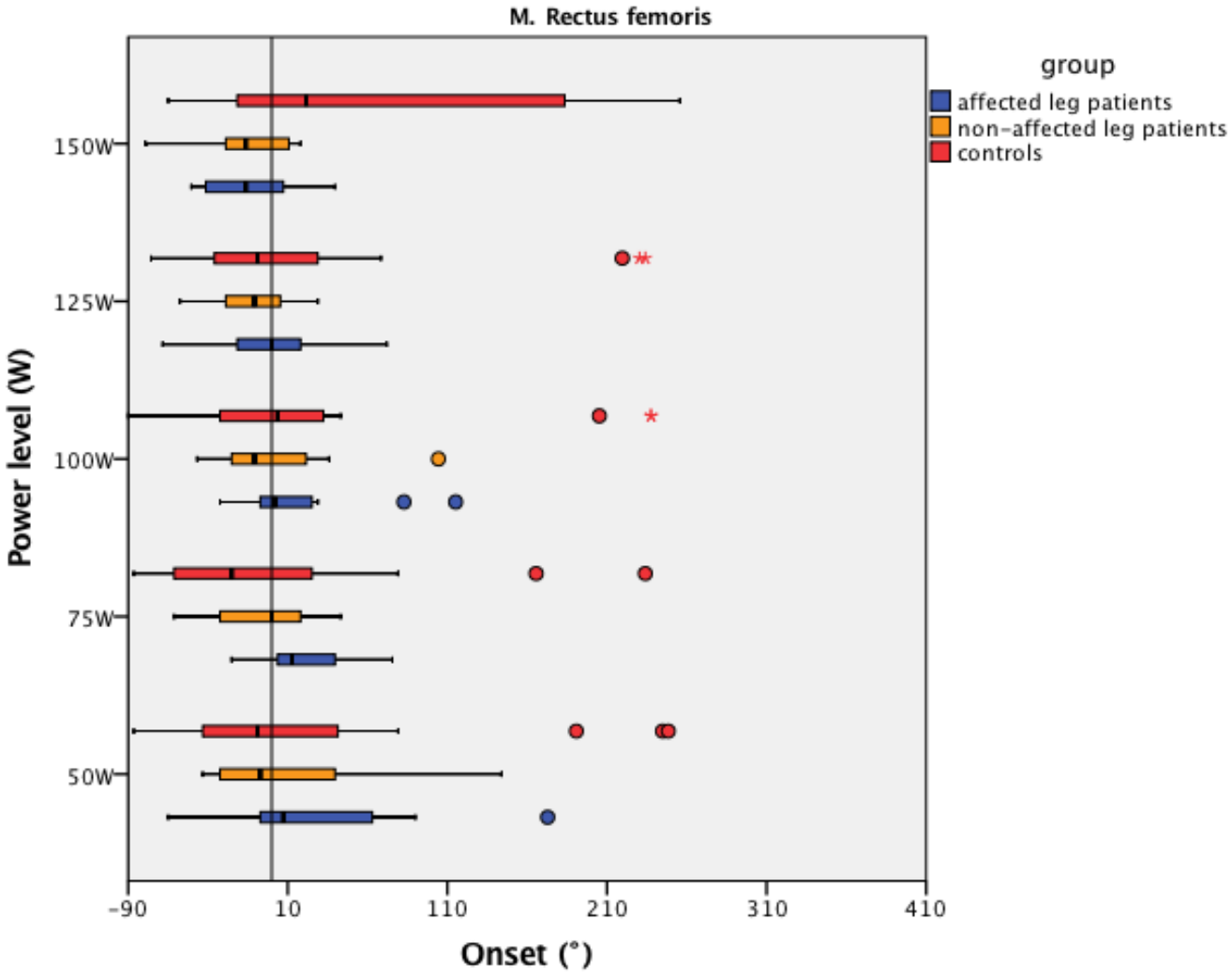

Figure 2: Group and power level Interaction on onset

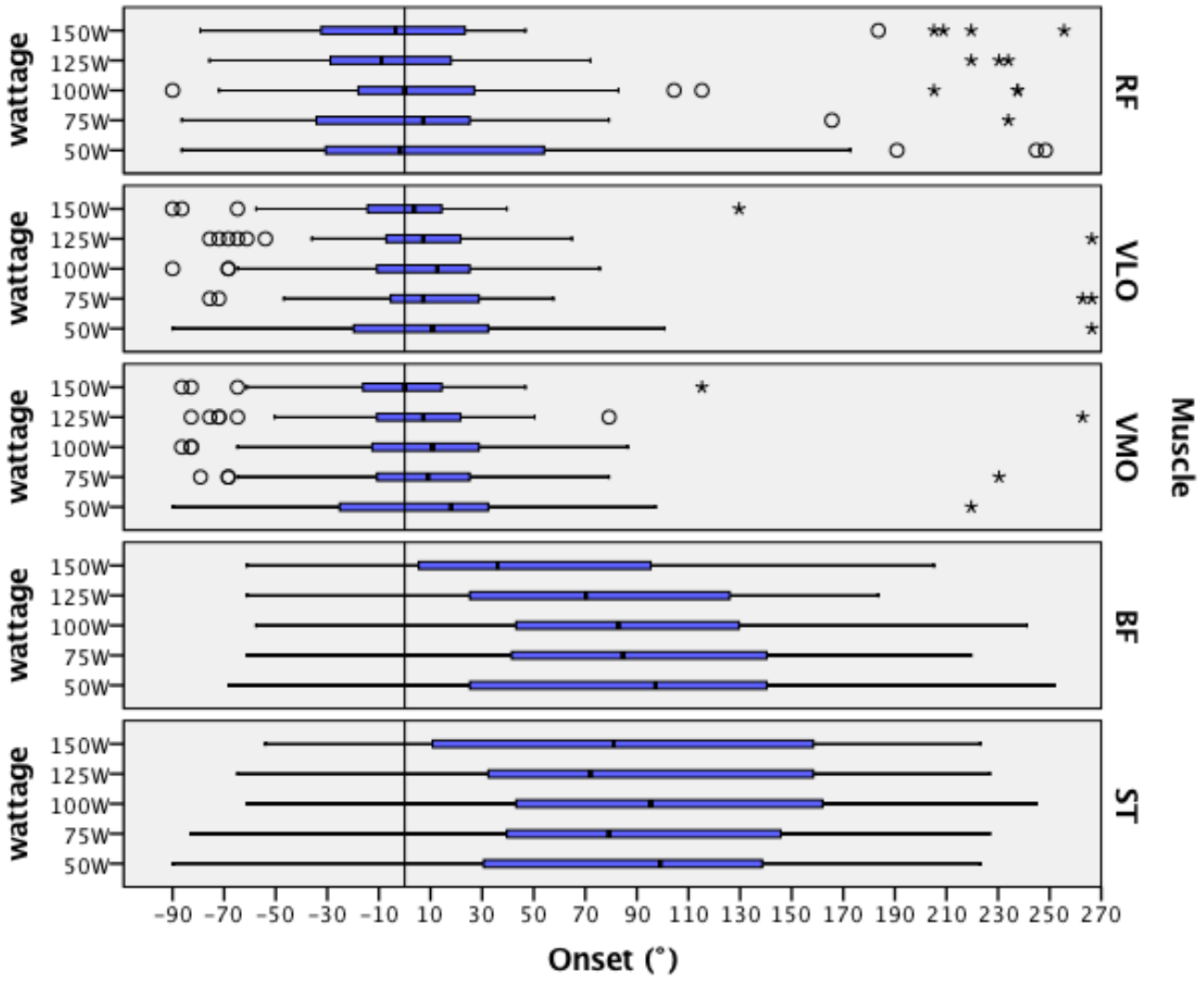

Figure 3: Power level effect on onset

Offset

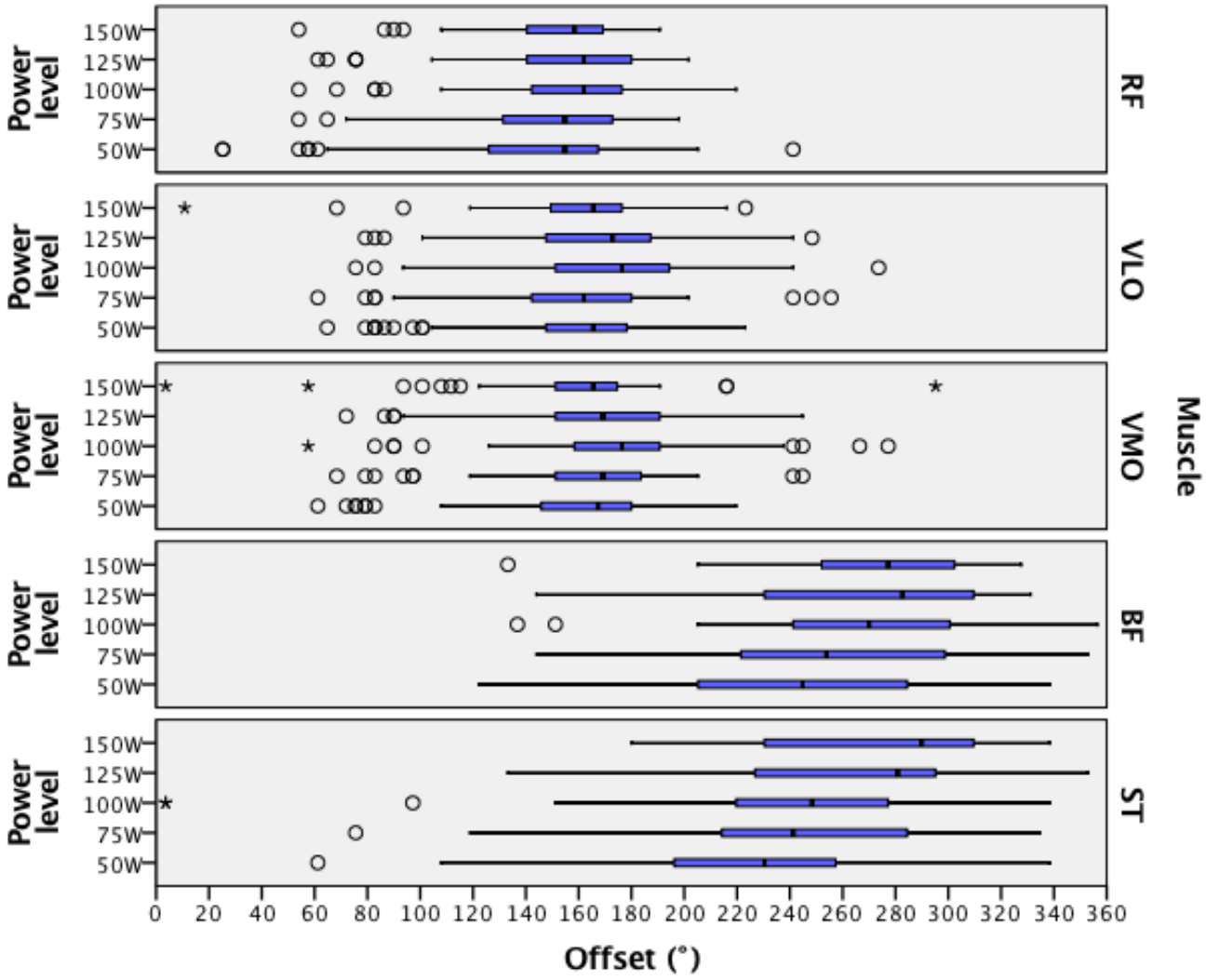

Figure 4: Power level effect on offset

Duration

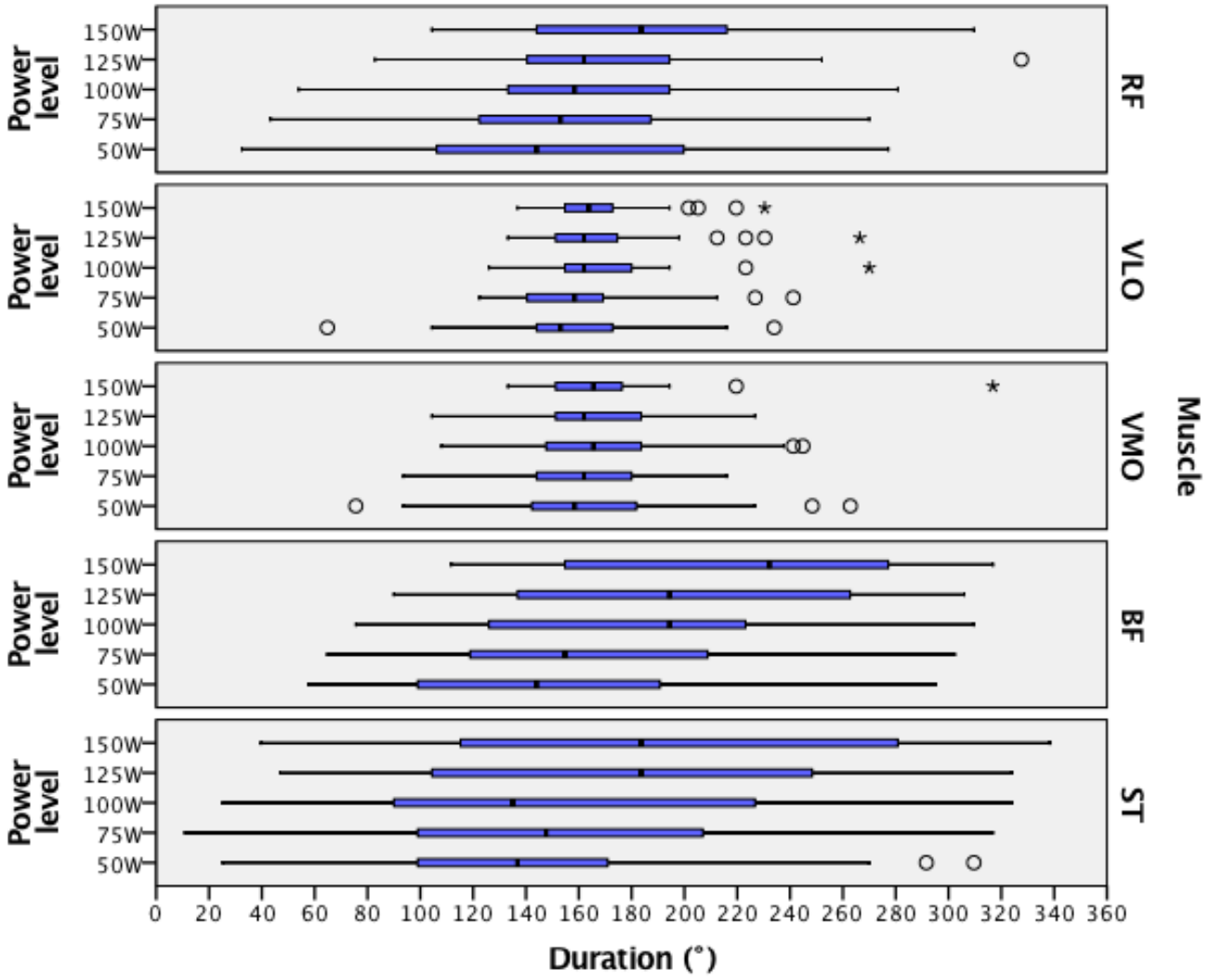

Figure 5: Power level effect on duration

Peak value

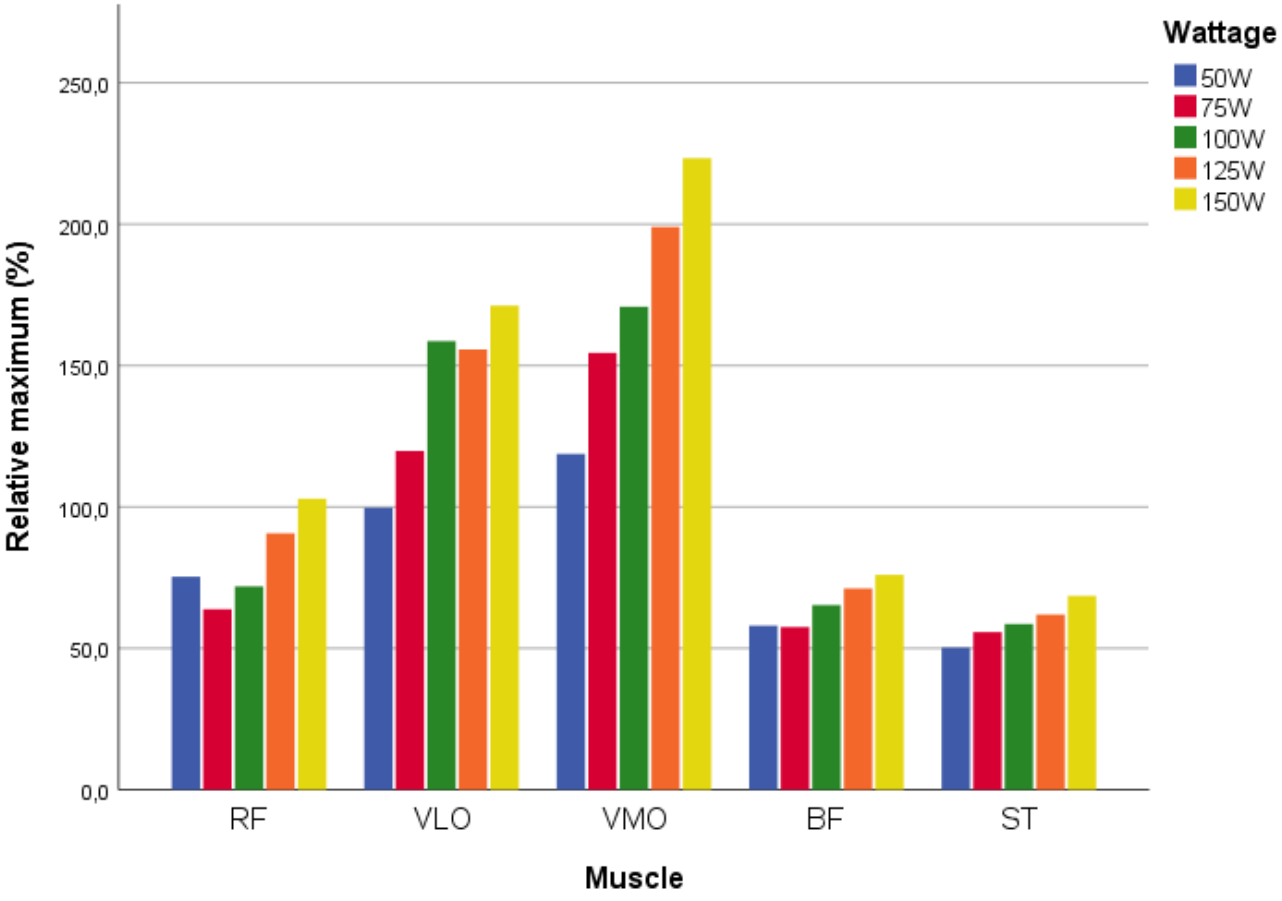

Figure 6: Power level effect on peak value/MVC

Timing of peak value

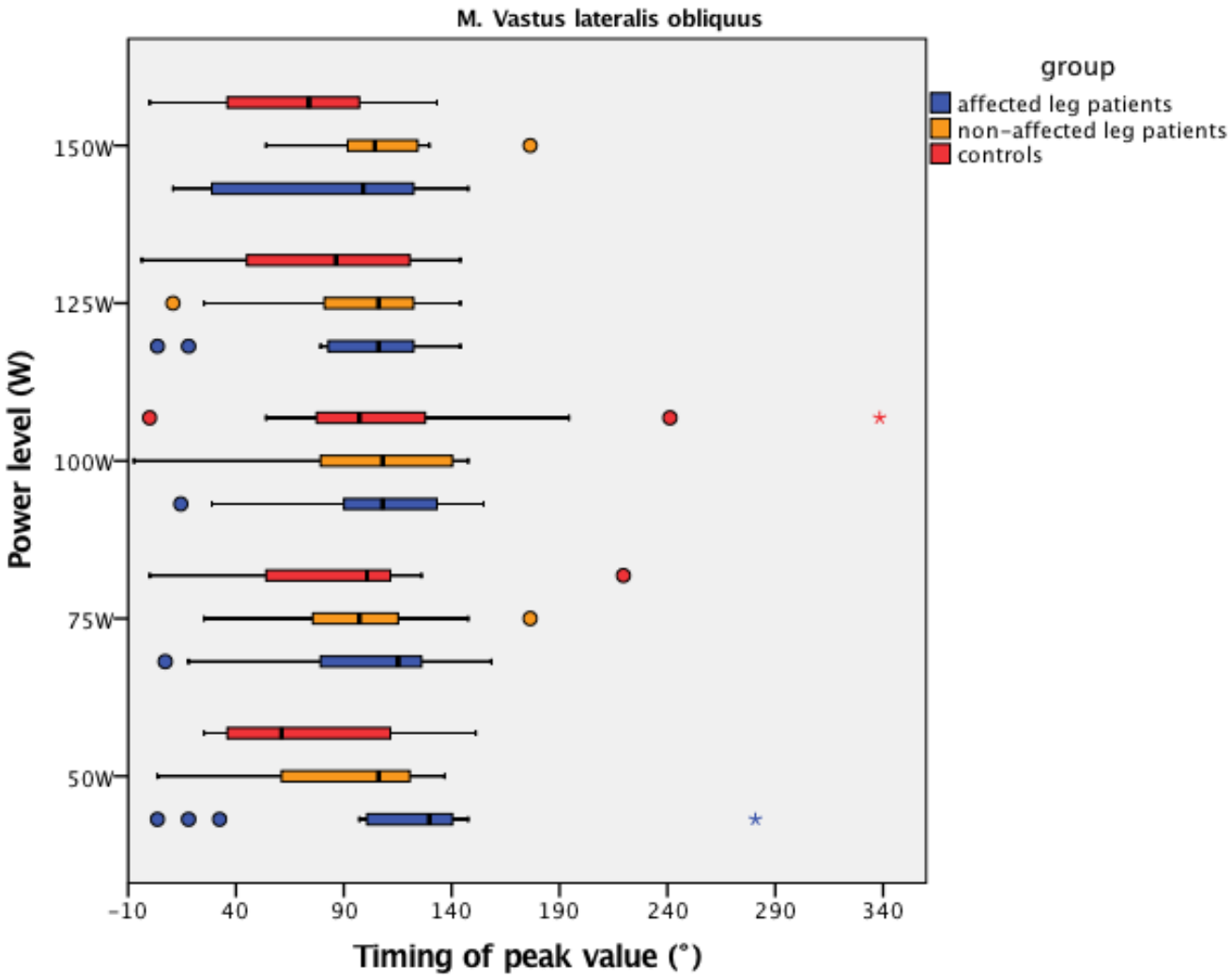

Figure 7: Group and power level interaction on timing of peak value

Isokinetic muscle strength

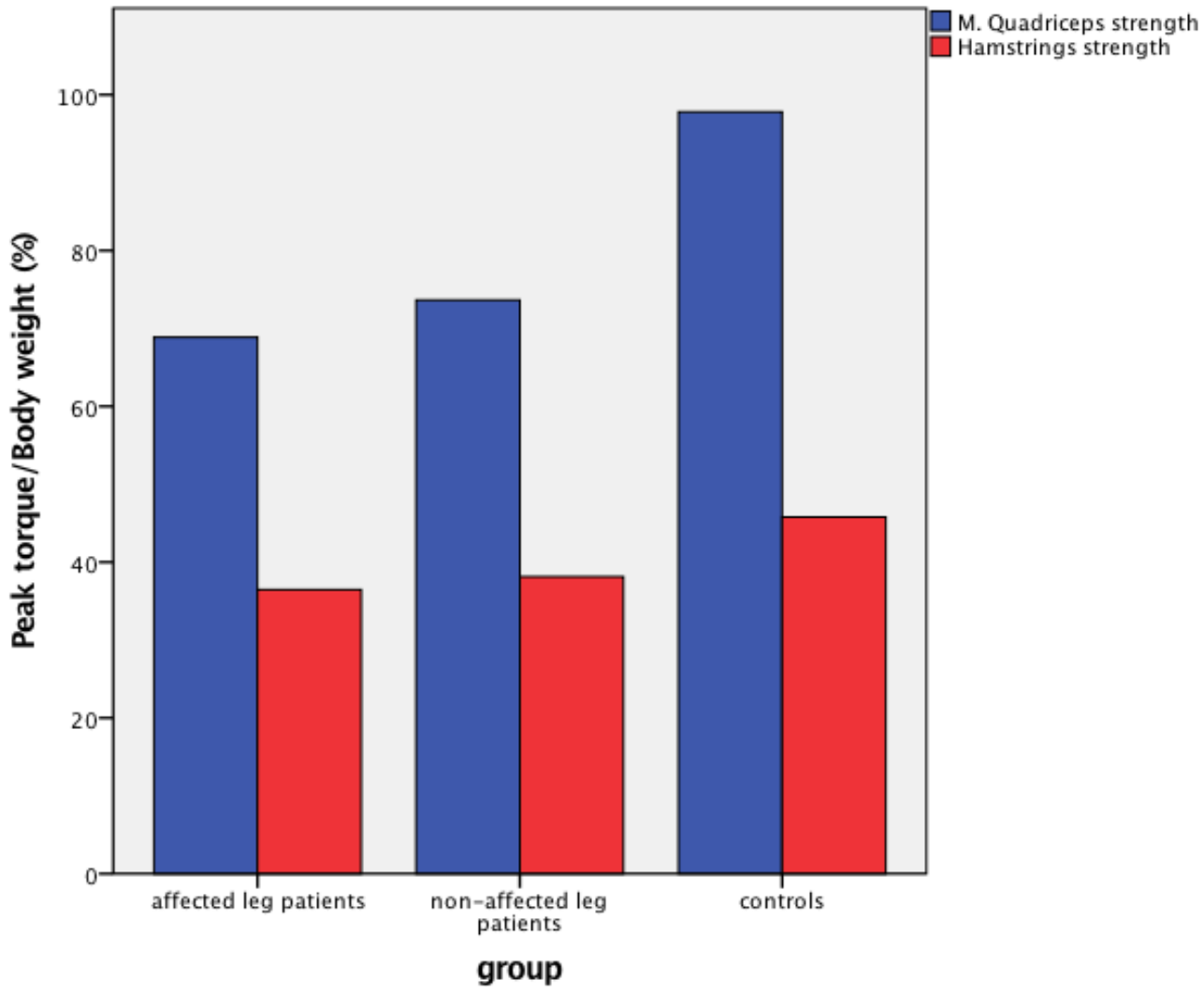

Figure 8: Group effect on peak torque/body weight