Science Meets Practice- Tampere
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Biomechanical Differences in Flywheel Squat vs Barbell Back Squat

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Jyväskylän yliopisto

Introduction

- The squat is one of the most frequently used strength exercises
  - BW or added resistance
  - Variations in depth and placement of external load
- The squat is considered a closed chain exercise where the feet are fixed to the ground and the force is expressed through the end by moving the rest of the body and the added resistance
- Effective and safe movement when performed correctly
- Everyone from novice exercisers to professional athletes are using the squat to improve their quality of life or enhancing their athletic performance
- Squat movement pattern is similar to many daily activities
- It is a multi-joint movement that includes ankle, hip, and knee joint
- Major muscles used in squat are quadriceps, hip extensors, and glutes
  - Abdominal muscles play a key role in maintaining an upward position

Introduction

- In the barbell back squat the barbell is placed behind the neck across the upper back and resistance is adjusted by adding weight plates on both ends of the barbell
- The movement starts with eccentric muscle contractions by lowering the bar by flexing the hip and knee joints
- In the concentric phase the hip and knee joints are extending, and the ankle is plantar flexing

Introduction

- A.V.Hill is one of the pioneers of studying muscle contractions and one of the first experiments he did with a flywheel device occurred in 1922
- National aeronautics and Space Administration (NASA) has been utilizing flywheel devices on their space flights since the 1990’s
- Strength training for astronauts is crucial in microgravity since muscle loss occurs at a higher rate than at sea level
- Flywheel training devices have been adopted into rehabilitation processes and into professional sports in the recent years
- The main difference in resistance between free weights and flywheel is that in free weights the resistance stays constant throughout the repetition and between repetitions while in flywheel the resistance adjusts with the amount of muscle force that is being applied, so the resistance can change drastically within and between repetitions

Introduction

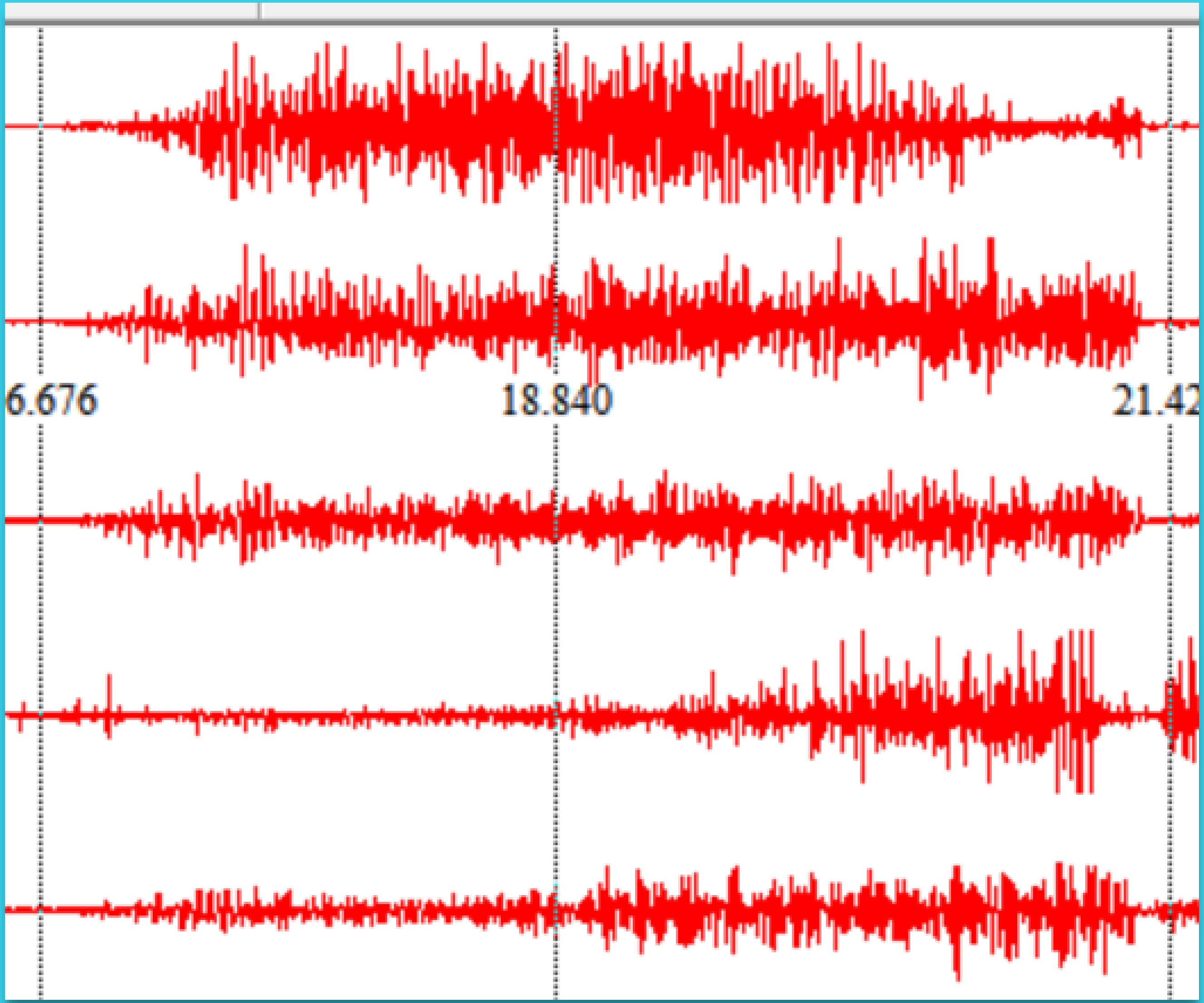
- In the barbell back squat the lower back undergoes high pressures and there is a risk of lower back injury especially in novice squatters
- The flywheel squat can be performed with a harness or with a belt, both of which are safer on the lower back since they alleviate the pressure and distributes it on the shoulders and the hips
- A limitation of using free weights is that the resistance stays constant throughout the repetition meaning that the greatest amount of resistance that can be used is limited to the weakest point of the repetition

Introduction

- Previous cross sectional studies using flywheel devices have focused on comparing multiple repetitions of either squats or leg press exercises
- Variables that have been studied are muscle activity with EMG, force production and kinematics
- Longitudinal comparison studies have looked at muscle mass gains, rate of force development, change of direction and other specified skills for athletes in a certain sport
- Findings in these studies have been diverging
- Major findings can be concluded that the flywheel can have similar benefits than conventional free weight training and in more specific tasks where explosive power and eccentric force is needed it can be superior

Barbell Back Squat

- Muscle activity during squats can be measured with EMG electrodes
- Muscle activity (from top to bottom) in RF, VL, VM, BF, and GM muscles during barbell BS in this study



Flywheel Isoinertial Exercise Device

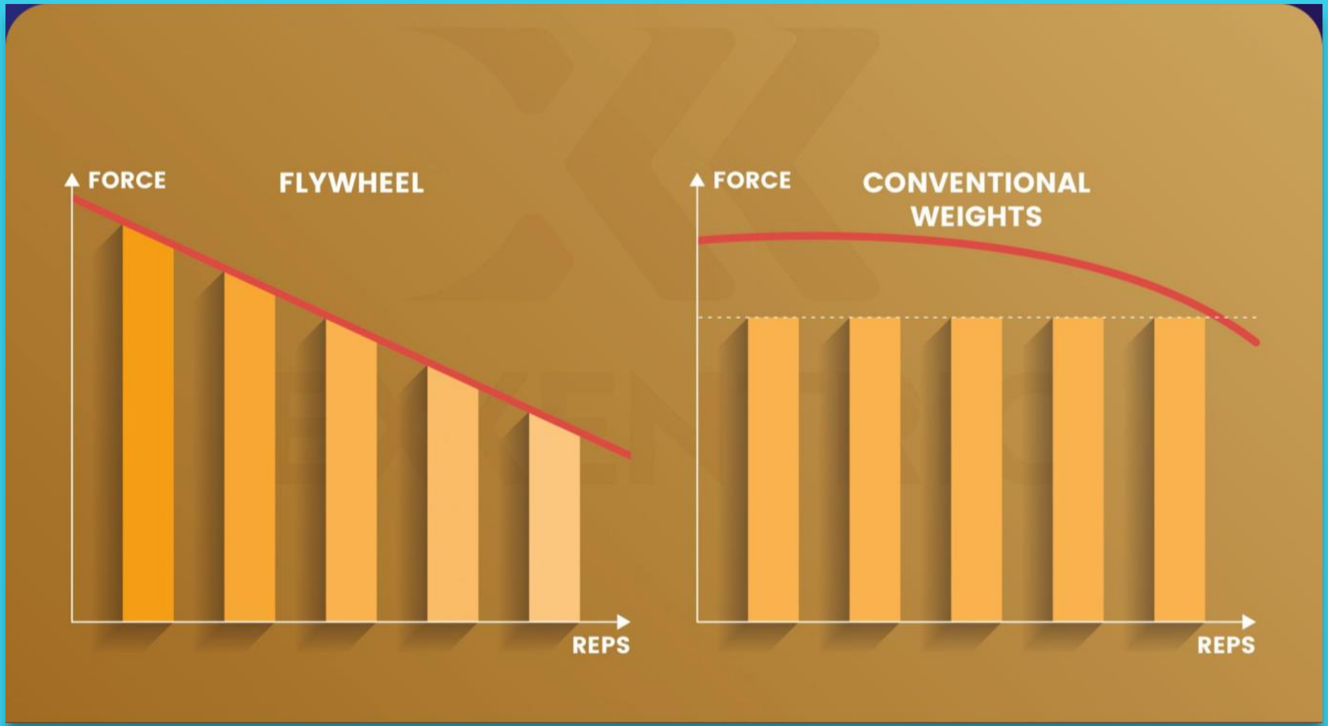
- The use of flywheels as resistance dates back to 1796 when a device called Gymnasticon was introduced by Francis Lowndes. Gymnasticon was designed to be used as a full body exercise device
- By the end of the 20th century, first commercially available flywheel exercise devices were introduced
- Within the last decade, flywheel exercise devices have been used in improving athletic performance, preventing injuries, and rehabilitation purposes
- There are strong evidence that flywheel training improves muscle strength, power and hypertrophy in healthy subjects and athletes of different sports

Flywheel Isoinertial Exercise Device

- In flywheel training the resistance created through moment of inertia of the flywheel (kg m^2)
- The flywheel is accelerated and decelerated with muscle force so the harder the athlete is able to push on the concentric phase, the harder the flywheel pulls back in the eccentric phase
- The device consists of one or more flywheels connected to a rotating shaft. The flywheels start to rotate around its axel by pulling on a rope that is attached to it.
- In the concentric action, kinetic energy is transferred to the flywheel. When the rope is pulled to its maximum length, the flywheel continues to spin and winds the rope back on the shaft again which then requires eccentric muscle action to try to slow down the flywheel and its kinetic energy.
- Using larger or additional flywheels creates more inertia, which requires more force to increase the speed of the flywheel

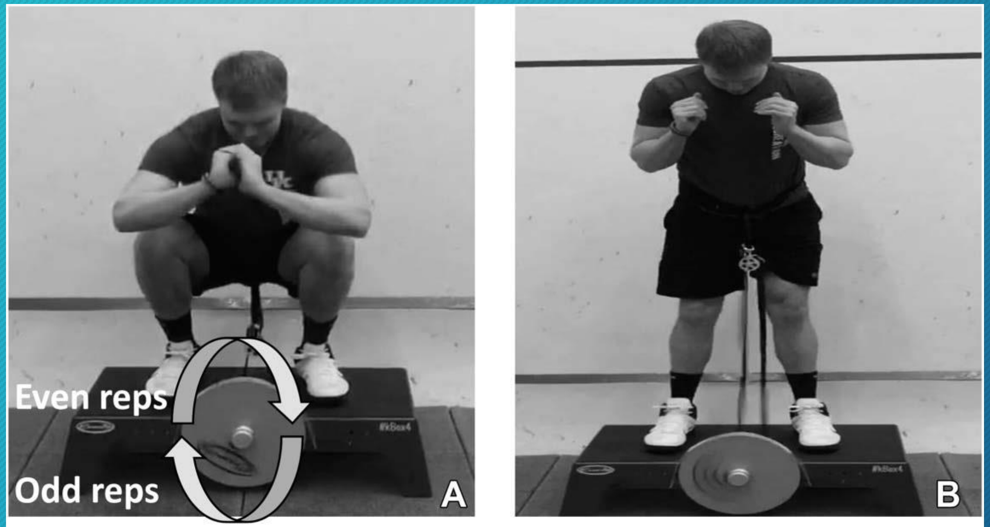
Flywheel Isoinertial Exercise Device

- The biggest difference between flywheel resistance and gravity-based resistance is that in gravity-based resistance the resistance stays constant throughout the movement, while in flywheel, the resistance alters throughout the movement and between repetitions based on the amount of muscle force used



Flywheel Isoinertial Exercise Device

- FW squats can be performed with belts or holding on to a bar but are usually performed with a harness. The benefit of using a harness is that it puts less stress on the lower back than conventional barbell BS. Squatting with a harness distributes the centre of gravity throughout the movement by decreasing the length of the moment arm which leads to less strain on the lower back



Flywheel Isoinertial Exercise Device

- Same lower body kinematical guidelines apply to the FW squat as barbell BS. The only kinematical difference is that since the loading of the external load is distributed differently the FW squat can be performed with greater hip flexion without the risk of injuring the lower back
- In the FW squat, the hands are free to move as well, which can help in maintaining balance with some people at lower knee angles. There is no such freedom in barbell BS since the arms are grabbing the bar

Flywheel Isoinertial Exercise Device

- In previous studies FW squats have been compared to barbell BS, front squats, leg press, and knee extension
- The results in regards of muscle activity vary between studies
- A study found that quadriceps muscle activity was similar in barbell BS and FW squat
- Another study compared FW squats to front squats, leg press and knee extensions and found that FW squats were superior in both eccentric and concentric phases in terms of muscle activity in vastus lateralis, vastus medialis, and rectus femoris
- Greater muscle activity can be achieved with FW squats throughout the whole squat movement since the load varies and the muscles are under maximal tension during the whole range of motion
- Greater muscle activity was seen at specific knee angles in a study that compared FW unilateral knee extensions to unilateral weight stack knee extensions and concluded that higher muscle activity noted with FW exercise compared to conventional gravity-based could be attributed to its unique iso-inertial loading features

Flywheel Isoinertial Exercise Device

- Training studies have found that eccentric overload training is superior to traditional weight training in developing muscle hypertrophy, maximal strength and power which of the latter two are in key importance in most sports
- Many studies have found superior results in muscle hypertrophy, maximal strength and power in FW training compared to conventional strength training
- FW training have also been found to yield superior results compared to conventional training methods in functional tests like vertical jumps, running sprints and change of direction
- However, there is no consistency in these studies since all used very different protocols and executions in their training studies regarding the inertial load, measuring tools, exercises used, age and previous training experience of the participants amongst others

Aim And Purpose of The Study

- Differing from previous studies, this study will focus on heavy loads (1RM) and the aim and purpose of the study is to find out how does conventional gravity-based strength training (in this case barbell BS) compared to FW squats in terms of muscle activity and concentric and eccentric force production in maximal one repetition performance
- This is something that has not been studied before and the results of this study can benefit especially athletes that use maximal loads in their training program
- **Research question:** How does FW squat differ from barbell BS in terms of muscle activity, force production, knee and hip angles and angular velocities?

Methods

- Participants
  - 14 healthy athletic male subjects (age 25.6 ± 3.3 years, height 187.6 ± 7.3 cm, mass 91.4 ± 8.7 kg, 1RM barbell back squat 135.4 ± 19.9 kg)
  - Most of the participants were athletes or previous athletes
  - All participants had to have at least two years of experience of heavy strength training, especially in squatting
  - The subjects did not have any ongoing injuries or neuromuscular disorders that would prevent or hinder them from performing maximal squats

Study Design

- Participants came in to do a familiarization session that lasted for 30 minutes at least five days prior to data collection
- The study was conducted as a cross-sectional study, so all the measurements for one subject were collected in the same session
- The subjects performed squats in two settings: barbell back squat and flywheel squat with harness
- The order of the squats was randomized so that half of the participants started with the barbell back squat, and the other half started with the flywheel squat

Study Design

- The data collection session lasted for two hours per participant
- The subject was instructed through a standardized warmup
- The participants did pre and post isometric MVC leg press tests
- Each participant performed three maximal trials with three minutes of rest between sets. The highest peak force was considered as their maximal. The isometric leg press device was set so that knee angle was at 90 degrees

Barbell Back Squat

- In the barbell back squat the subject had to give an approximate estimation of their 1RM back squat
- The first load was at 40% of their estimated value and they performed five repetitions with that load. After this the subject only had to perform one repetition with each load
- The loads progressively increased until maximal was reached
- The participants performed in total between 5 and 8 sets of the barbell back squat depending on how long it took to reach their maximum with 3-5 minutes of rest between sets
- The participants were instructed to squat so that their thighs would lie parallel to the floor
- The squat rack had safety bars placed so that when the participant was not able to lift the weight, they would lower it on the safety bars and a spotter was standing right behind them at all times in the heavier squats

Flywheel Squat

- In the flywheel squat, the protocol was the same for each participant
- The participants were given 3-5 minutes rest between each trial
- The starting position was thighs parallel to the floor. Then the subject was asked to stand up with approximately 80% effort to get momentum into the flywheel
- In the following repetition the subjects were asked to push maximally in the concentric direction and to let the flywheel pull them down about a third in the eccentric part before they start to apply breaking force and try to change the direction of the flywheel as quickly and forcefully as possible into the last maximal concentric action
- The participants were asked to perform the squats down to thighs parallel to the floor, so same as in the barbell back squat

Trial number	Flywheel moment of inertia (kg m^2)
1	0.070
2	0.140
3	0.210
4	0.280
5	0.355

Flywheel Squat

- In FW squats a harness was used.
- The harness puts less stress on the lower back by distributing the force lower on the hips
- This takes away the lever arm that puts stress on the lower back in BS
- The two metal rings at the end of the harness were attached to the pulling force meter and FW setup

Flywheel Squat

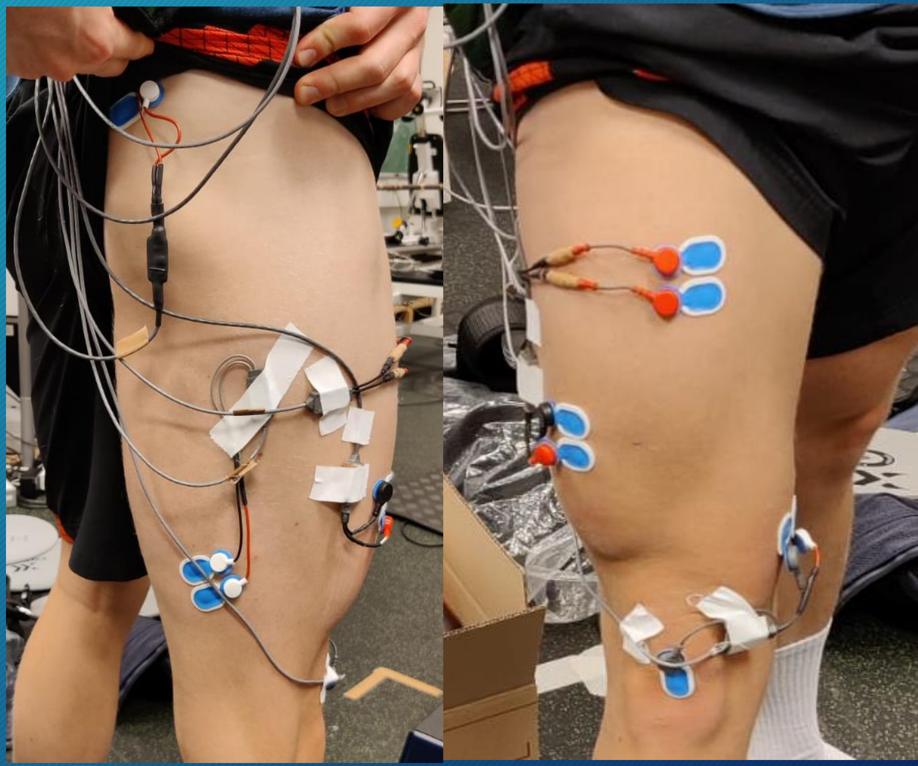
- The participant had the freedom to choose the footwear for their squats as long as they performed both the barbell back squat and the flywheel squat with the same shoes
- Lifting belts were allowed in the barbell back squat
- The participants had also freedom to choose the width of the squatting stance, but the once they settled on the stance width, tape markers were placed on the floor so that they would use the same stance width in all trials in both settings

Measurement Methods

- In the barbell back squat setting, Leoko barbell and weight plates (Leoko Oy, Tampere, Finland) were used
- For the flywheel squat, Exxentric kBox4 Pro with their flywheels and harnesses (Exxentric AB, Bromma, Sweden) was used in this study
- Forces were obtained from a force plate (University of Jyväskylä, Jyväskylä, Finland) in the barbell back squat and with a pulling force meter (University of Jyväskylä, Jyväskylä, Finland) in the flywheel squat
- All back squats were performed on the force plate and the pulling force meter was placed between the harness and the cable that is attached to the flywheel
- A custom-made force signal amplifier ForAmps was used as well (University of Jyväskylä, Jyväskylä, Finland)
- Force data was sampled at 1000 Hz. Data of average force and peak force in eccentric and concentric contractions was obtained

Measurement Methods

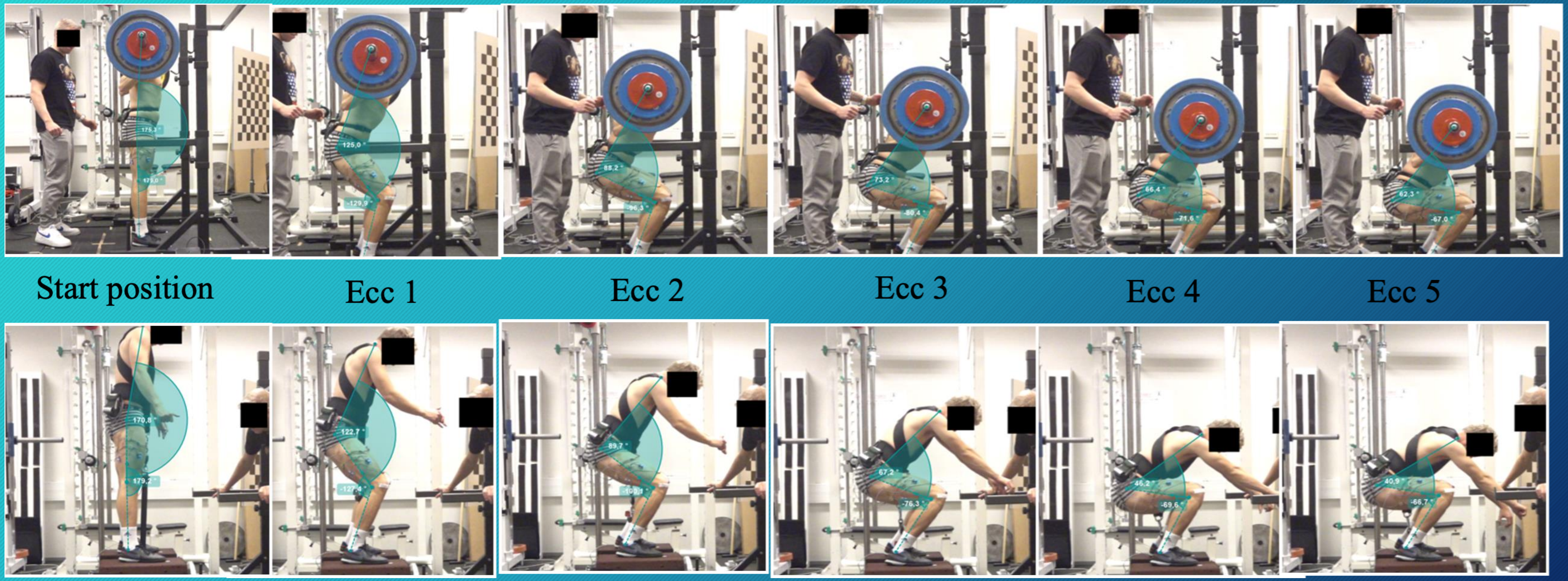
- Muscle activity was measured with Ambu BlueSensor N silver – silver chloride bipolar surface EMG electrodes (Ambu A/S Ballerup, Denmark)
- The skin was prepared by shaving, sand papering and rubbing alcohol
- The measured muscles were rectus femoris (RF), vastus lateralis (VL), vastus medialis (VM), biceps femoris (BF), and gluteus maximus (GM)
- The electrodes were placed on the muscles according to the SENIAM guidelines
- The sEMG electrodes were attached to a wireless Noraxon TeleMyo 2400R transmitter (Noraxon U.S.A Inc, Arizona, USA)
- Hardware filters were set as following: No notch 50/60 Hz filters, 1st order high pass filters set to 10 Hz +/- 10 % cutoff and 8th order Butterworth / Bessells low pass anti-alias filters set to 1000 Hz +/- 2 % cutoff
- Sample rate was set at 1000 Hz.



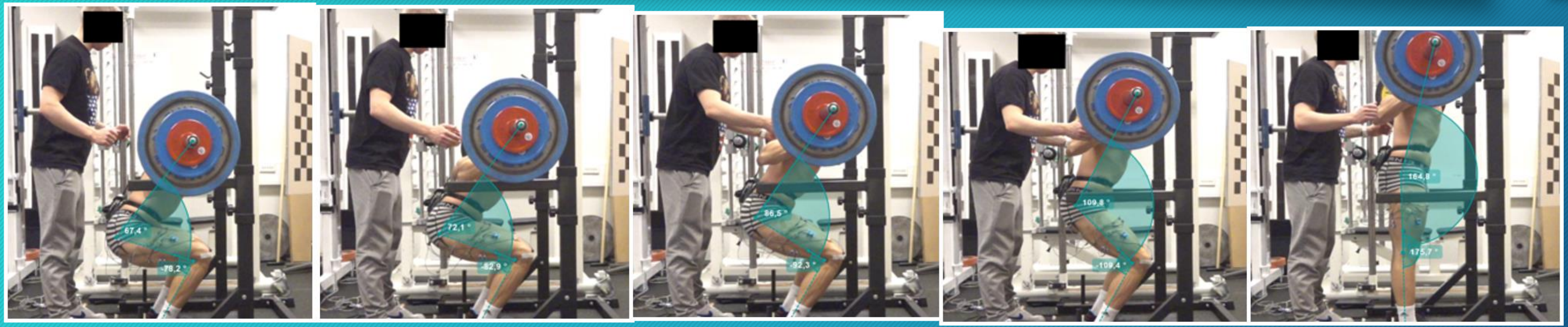
Data Analysis

- For each subject a successful 1RM barbell back squat was used as the reference repetition. In that repetition the eccentric and concentric parts were timed using a timer and frame by frame analysis in Kinovea
- Then for each participant each flywheel trial was timed in using the same method and the one that was closest to the barbell back squat in terms of full repetition total time, was chosen as their 1RM flywheel squat
- For a few participants, a separate comparison was also made by finding full repetition average force to be as close in the flywheel squat as to the barbell back squat
- Full repetition was further divided into a total of 10 sections (5 eccentric and 5 concentric)
- This was done by dividing the eccentric and concentric times into five parts

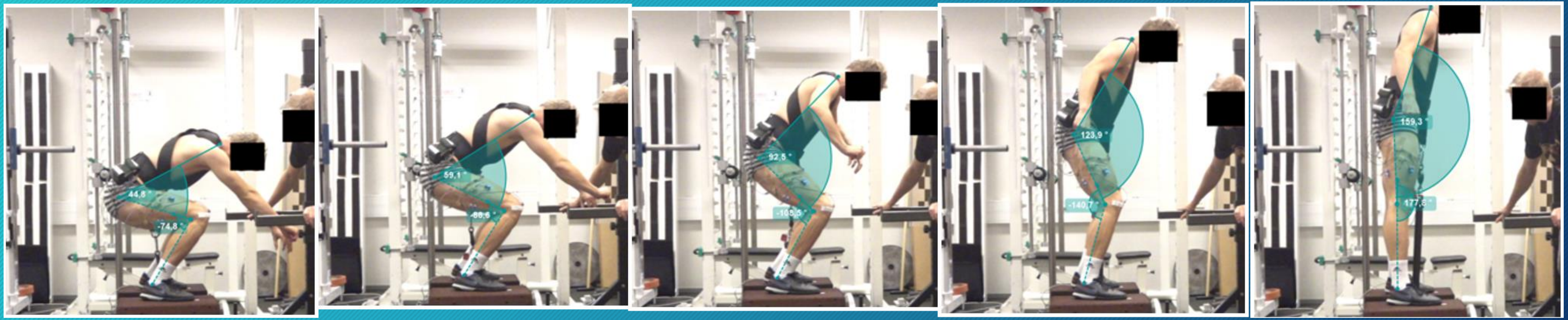
Eccentric subsections



Concentric Subsections

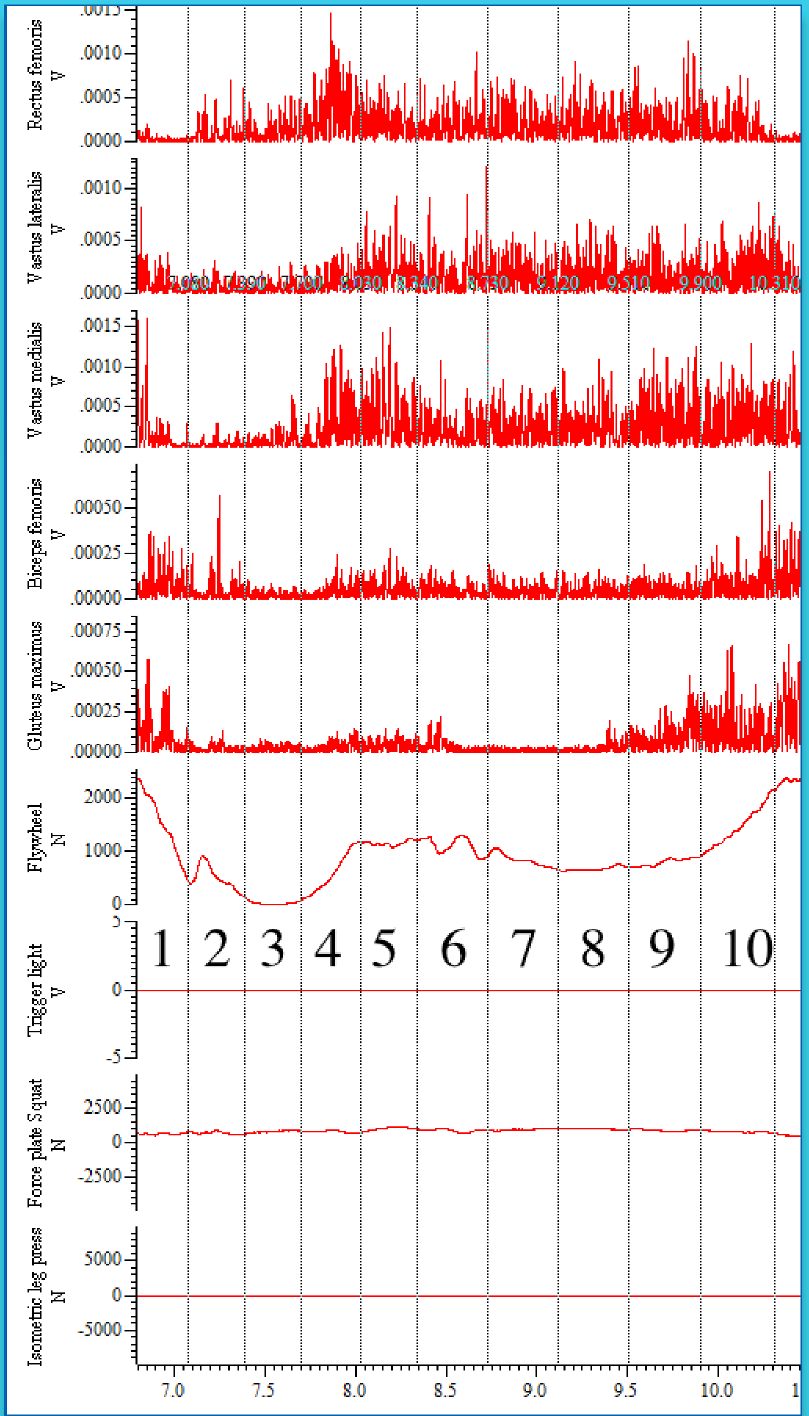


Con 1 Con 2 Con 3 Con 4 Con 5



Data Analysis

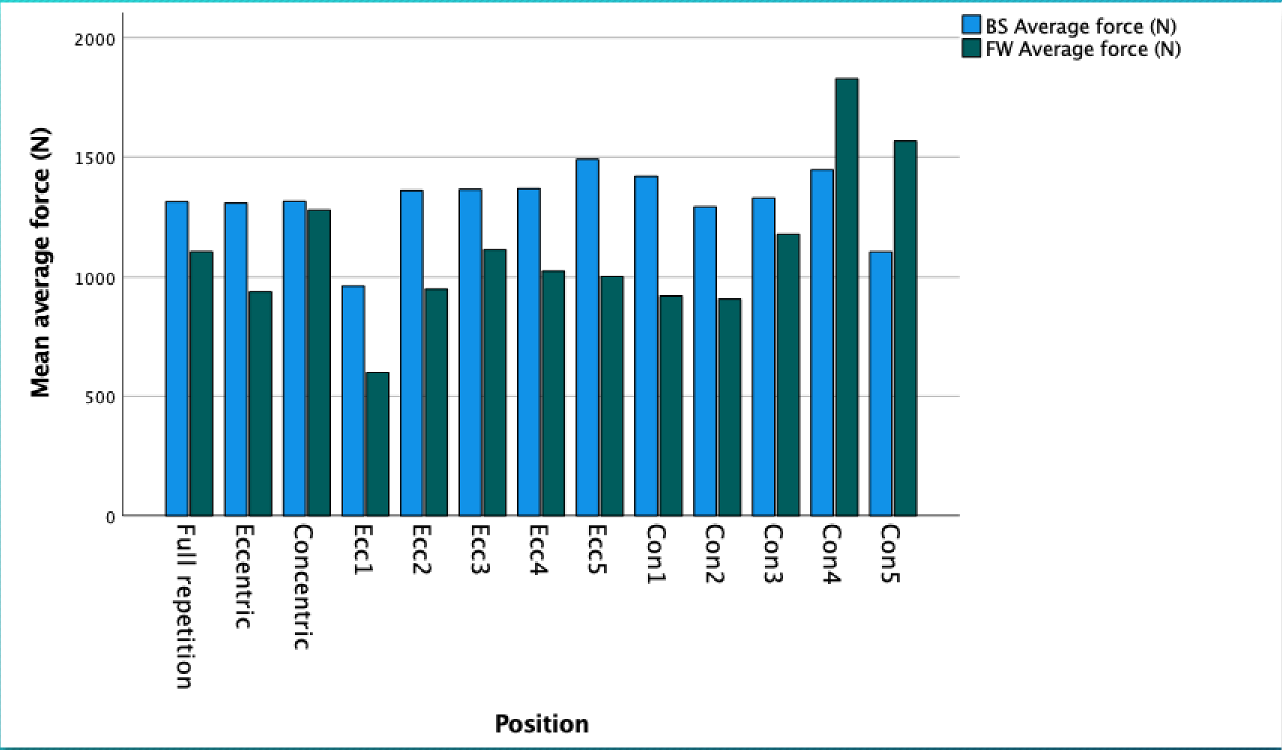
- In the back squat force signal, the subject's bodyweight was subtracted from the total force to make it comparable to data given by the pulling force meter in the flywheel squat
- Average and peak forces were obtained and reported for the full repetition, eccentric part, concentric part, and all 10 sub sections described above. Force values are presented in Newtons
- EMG data was rectified and reported as RMS amplitude within each sub section. Averages were also calculated for full repetition, eccentric and concentric parts. EMG data is presented in mV



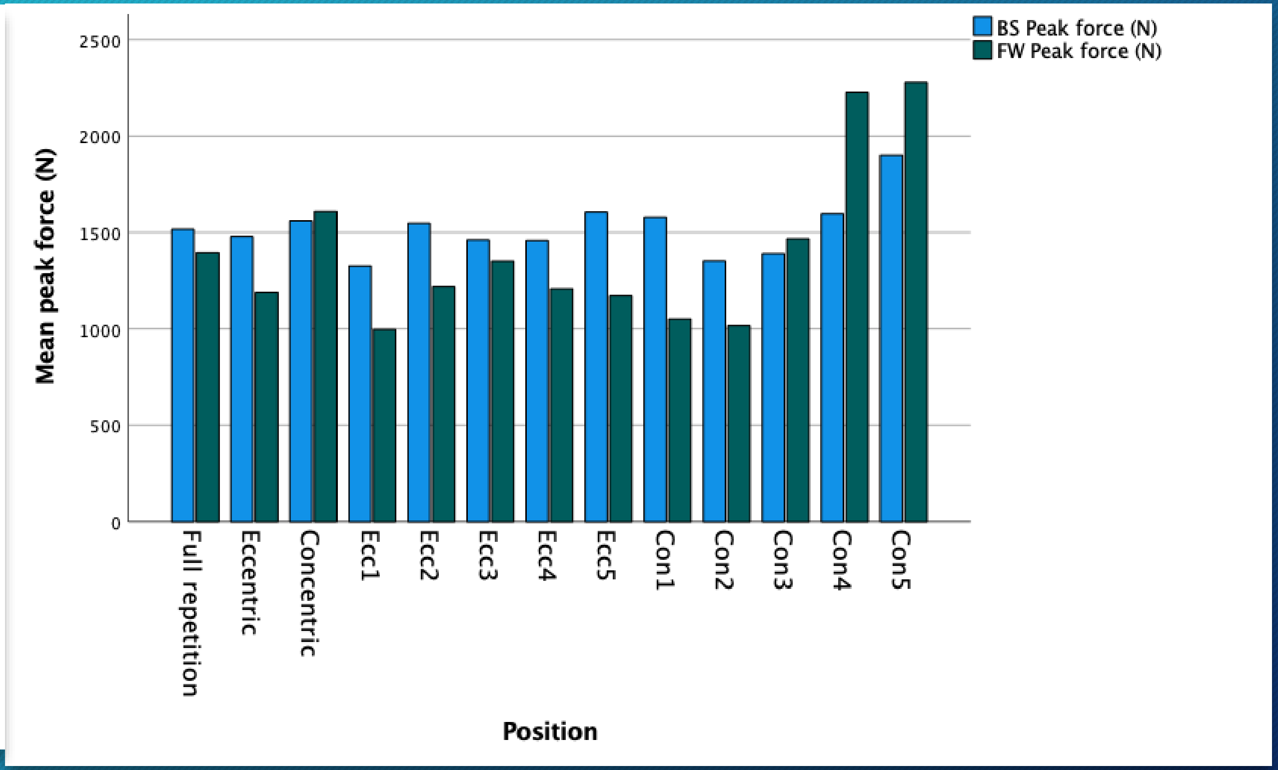
Data Analysis

- For kinematic analysis, joint angles were analyzed using Kinovea. Since the videos were recorded at 100 frames per second, each frame represents 1/100 of a second
- At the start of each sub section, knee- and hip angles were obtained
- Knee- and hip angular velocities were calculated by dividing the change in the angle between two sub sections with the change in time
- Angular velocity is reported as degrees / seconds, where negative values represent eccentric actions

Results



BS Average force (N)
FW Average force (N)
Mean average force (N)
2000
1500
1000
500
0
Full repetition
Eccentric
Concentric
Ecc1
Ecc2
Ecc3
Ecc4
Ecc5
Con1
Con2
Con3
Con4
Con5
Position



BS Peak force (N)
FW Peak force (N)
Mean peak force (N)
2500
2000
1500
1000
500
0
Full repetition
Eccentric
Concentric
Ecc1
Ecc2
Ecc3
Ecc4
Ecc5
Con1
Con2
Con3
Con4
Con5
Position

Results

Position	Statistics	BS Time (s)	FW Time (s)	BS Average force (N)	FW Average force (N)	% - Difference	BS Peak force (N)	FW Peak force (N)	% - Difference
Full repetition	Mean	**4.15**	**3.84**	**1322**	**1106**	**17.8% ***	**1525**	**1396**	**8.8 %**
	Std. Deviation	1.10	0.55	196	255	-	224	312	-
Eccentric	Mean	**1.90**	**1.95**	**1310**	**939**	**33.0% ****	**1480**	**1190**	**21.7% ***
	Std. Deviation	0.51	0.37	196	241	-	234	270	-
Concentric	Mean	**2.25**	**1.89**	**1335**	**1281**	**4.1 %**	**1570**	**1608**	**2.4 %**
	Std. Deviation	0.70	0.29	204	276	-	220	364	-

Position	Statistics	BS Cumulative Time (s)	FW Cumulative Time (s)	BS Average force (N)	FW Average force (N)	% - Difference	BS Peak force (N)	FW Peak force (N)	% - Difference
Ecc1	Mean	**0.38**	**0.39**	**963**	**601**	**46.3% ***	**1326**	**997**	**28.3% ***
	Std. Deviation	-	-	202	461	-	193	580	-
Ecc2	Mean	**0.76**	**0.78**	**1361**	**950**	**35.6% ***	**1546**	**1221**	**23.5 %**
	Std. Deviation	-	-	290	585	-	300	668	-
Ecc3	Mean	**1.14**	**1.17**	**1366**	**1115**	**20.2 %**	**1462**	**1351**	**7.9 %**
	Std. Deviation	-	-	232	353	-	241	328	-
Ecc4	Mean	**1.52**	**1.56**	**1369**	**1025**	**28.7% ***	**1459**	**1209**	**18.8% ***
	Std. Deviation	-	-	215	294	-	227	349	-
Ecc5	Mean	**1.9**	**1.95**	**1491**	**1002**	**39.2% ****	**1605**	**1173**	**31.1% ***
	Std. Deviation	-	-	271	387	-	313	441	-
Con1	Mean	**2.35**	**2.33**	**1420**	**920**	**42.7% ****	**1578**	**1051**	**40.1% ****
	Std. Deviation	-	-	213	192	-	292	309	-
Con2	Mean	**2.8**	**2.71**	**1294**	**908**	**35.1% ****	**1352**	**1017**	**28.3% ****
	Std. Deviation	-	-	192	213	-	199	268	-
Con3	Mean	**3.25**	**3.08**	**1331**	**1179**	**12.1 %**	**1390**	**1468**	**5.4 %**
	Std. Deviation	-	-	194	370	-	203	469	-
Con4	Mean	**3.7**	**3.46**	**1465**	**1828**	**22.1% ***	**1623**	**2227**	**31.4% ****
	Std. Deviation	-	-	217	534	-	246	586	-
Con5	Mean	**4.15**	**3.84**	**1166**	**1567**	**29.4% ***	**1905**	**2279**	**17.9% ***
	Std. Deviation	-	-	321	559	-	267	563	-

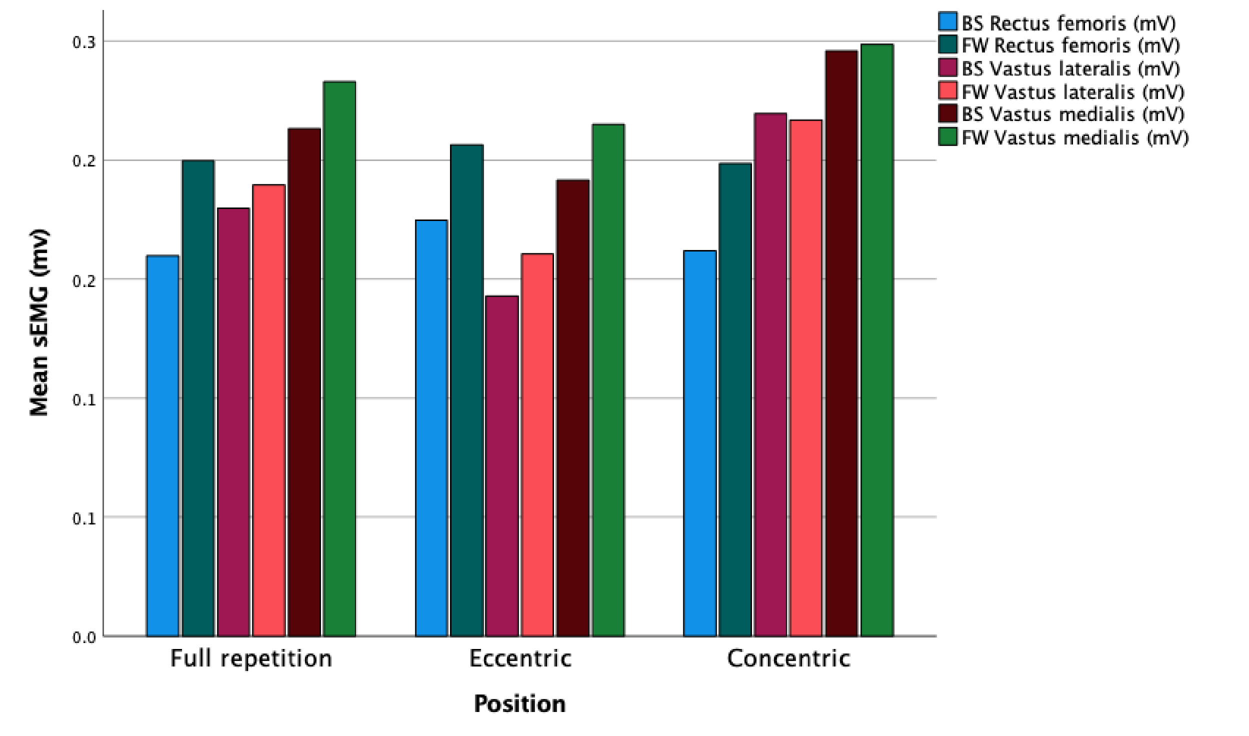
* Significance $p < 0.05$	Greater force in BS
** Significance $p < 0.001$	Greater force in FW

Position	Statistics	BS Average force (N)	FW Average force (N)	% - Difference	BS Peak force (N)	FW Peak force (N)	% - Difference
Full repetition	Mean	**1322**	**1145**	**14.4% ***	**1525**	**1417**	**7.3 %**
	Std. Deviation	196	255	-	224	312	-
Eccentric	Mean	**1310**	**983**	**28.5% ****	**1480**	**1209**	**20.1% ***
	Std. Deviation	196	241	-	234	270	-
Concentric	Mean	**1335**	**1311**	**1.8 %**	**1570**	**1632**	**3.9 %**
	Std. Deviation	204	276	-	220	364	-

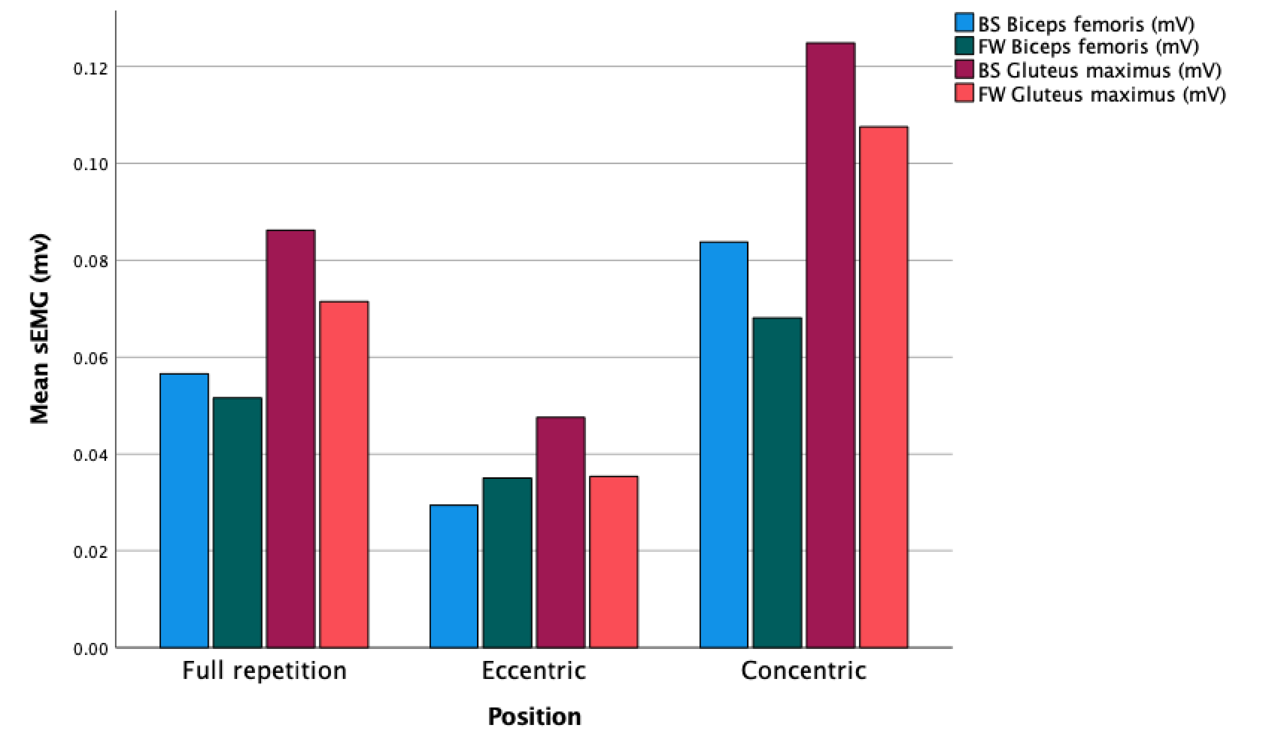
Position	Statistics	BS Average force (N)	FW Average force (N)	% - Difference	BS Peak force (N)	FW Peak force (N)	% - Difference
Ecc1	Mean	**963**	**699**	**31.8 %**	**1326**	**1056**	**22.7 %**
	Std. Deviation	202	461	-	193	580	-
Ecc2	Mean	**1361**	**1046**	**26.2% ***	**1546**	**1306**	**16.8 %**
	Std. Deviation	290	585	-	300	668	-
Ecc3	Mean	**1366**	**1124**	**19.4% ***	**1462**	**1351**	**7.9 %**
	Std. Deviation	232	353	-	241	328	-
Ecc4	Mean	**1369**	**1026**	**28.6% ***	**1459**	**1187**	**20.5% ***
	Std. Deviation	215	294	-	227	349	-
Ecc5	Mean	**1491**	**1021**	**37.4% ****	**1605**	**1146**	**33.4% ****
	Std. Deviation	271	387	-	313	441	-
Con1	Mean	**1420**	**929**	**41.8% ****	**1578**	**1067**	**38.6% ****
	Std. Deviation	213	192	-	292	309	-
Con2	Mean	**1294**	**909**	**35% ****	**1352**	**1030**	**27.1% ****
	Std. Deviation	192	213	-	199	268	-
Con3	Mean	**1331**	**1197**	**10.6 %**	**1390**	**1484**	**6.5 %**
	Std. Deviation	194	370	-	203	469	-
Con4	Mean	**1465**	**1851**	**23.3% ***	**1623**	**2276**	**33.5% ****
	Std. Deviation	217	534	-	246	586	-
Con5	Mean	**1166**	**1664**	**35.2% ***	**1905**	**2296**	**18.6% ***
	Std. Deviation	321	559	-	267	563	-

* Significance $p < 0.05$	Greater force in BS
** Significance $p < 0.001$	Greater force in FW

Results

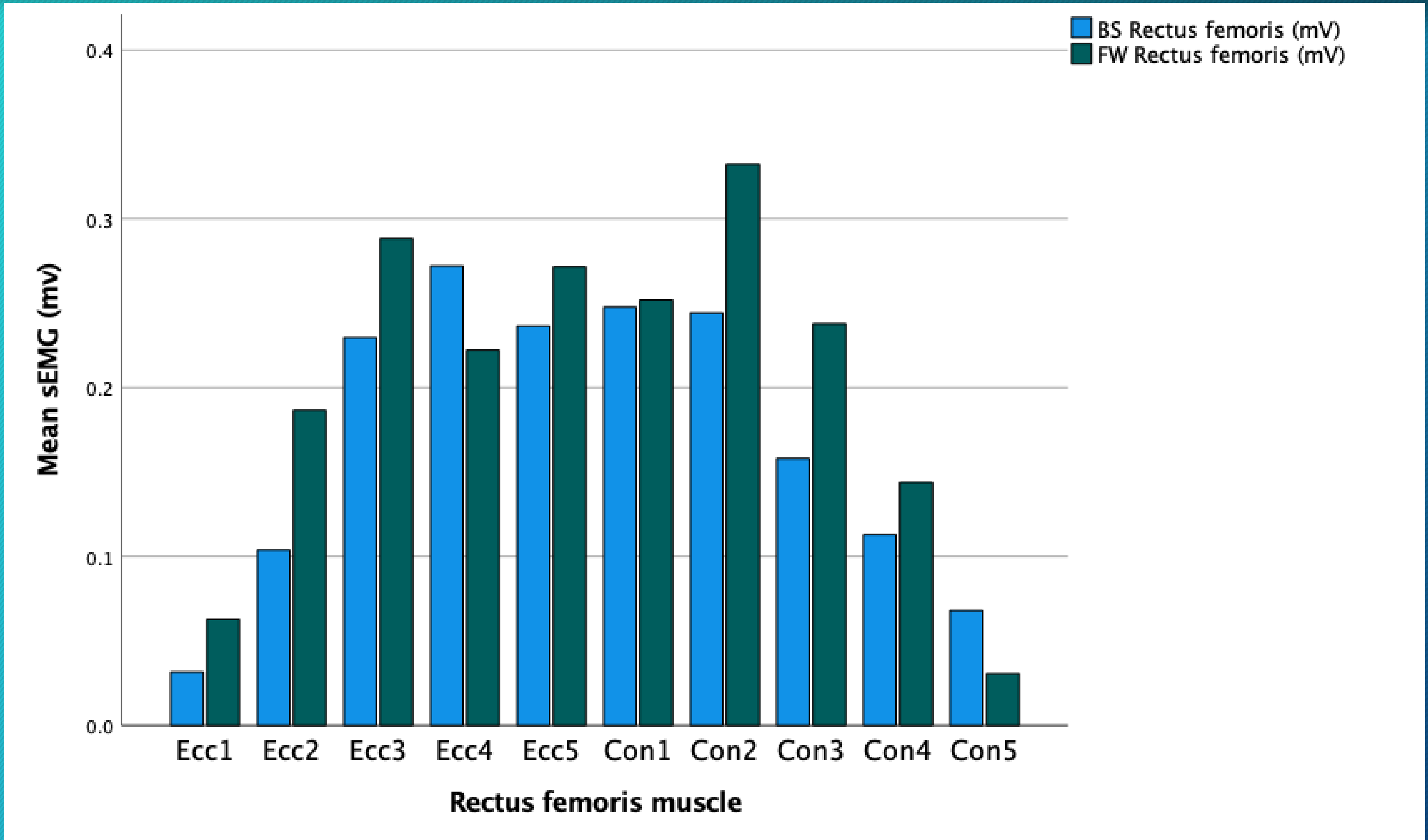


BS Rectus femoris (mV)
FW Rectus femoris (mV)
BS Vastus lateralis (mV)
FW Vastus lateralis (mV)
BS Vastus medialis (mV)
FW Vastus medialis (mV)
Mean sEMG (mv)
0.3
0.2
0.2
0.1
0.1
0.0
Full repetition
Eccentric
Concentric
Position



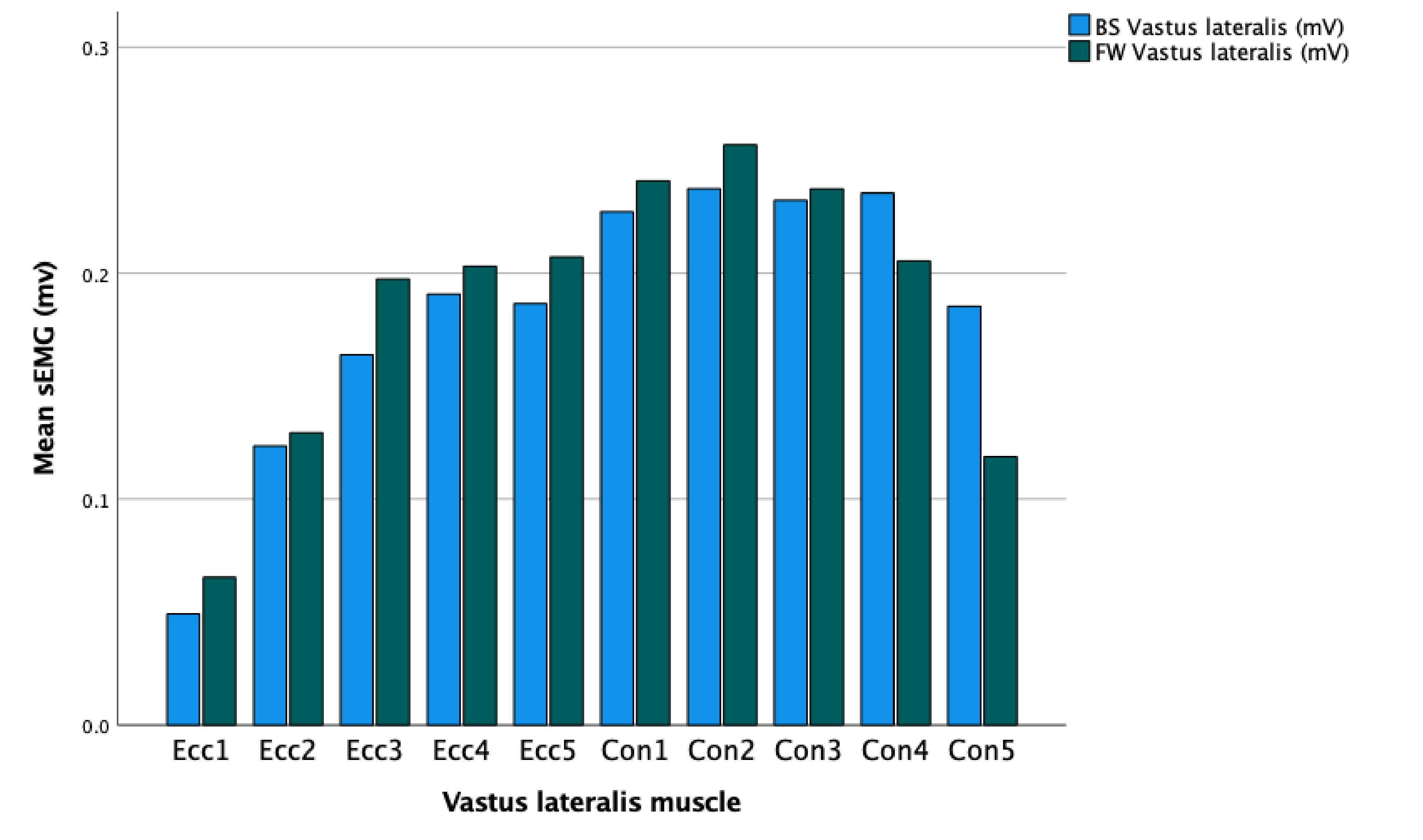
BS Biceps femoris (mV)
FW Biceps femoris (mV)
BS Gluteus maximus (mV)
FW Gluteus maximus (mV)
Mean sEMG (mv)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Full repetition
Eccentric
Concentric
Position

Results



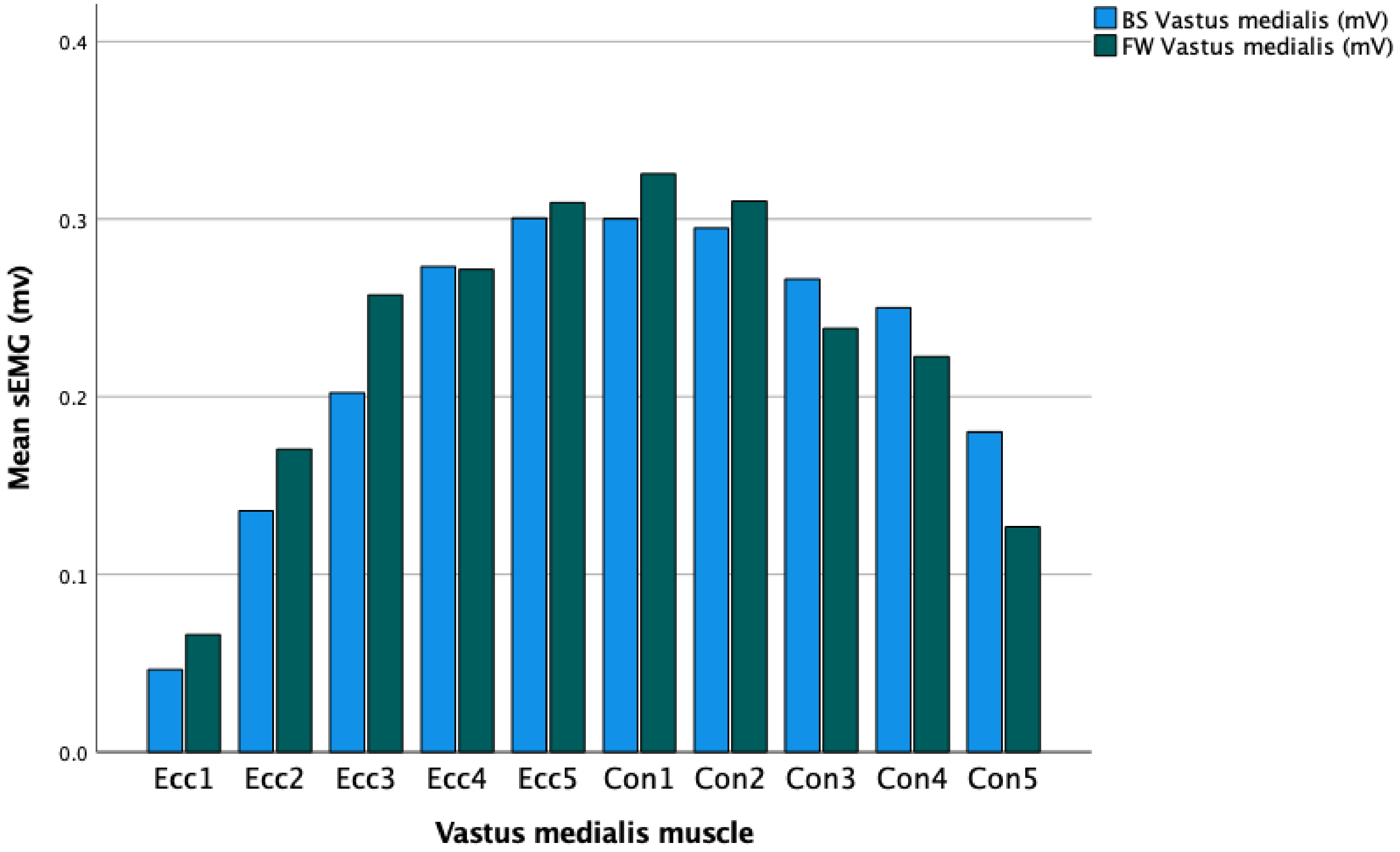
BS Rectus femoris (mV)
FW Rectus femoris (mV)
Mean sEMG (mv)
0.4
0.3
0.2
0.1
0.0
Ecc1
Ecc2
Ecc3
Ecc4
Ecc5
Con1
Con2
Con3
Con4
Con5
Rectus femoris muscle

Results



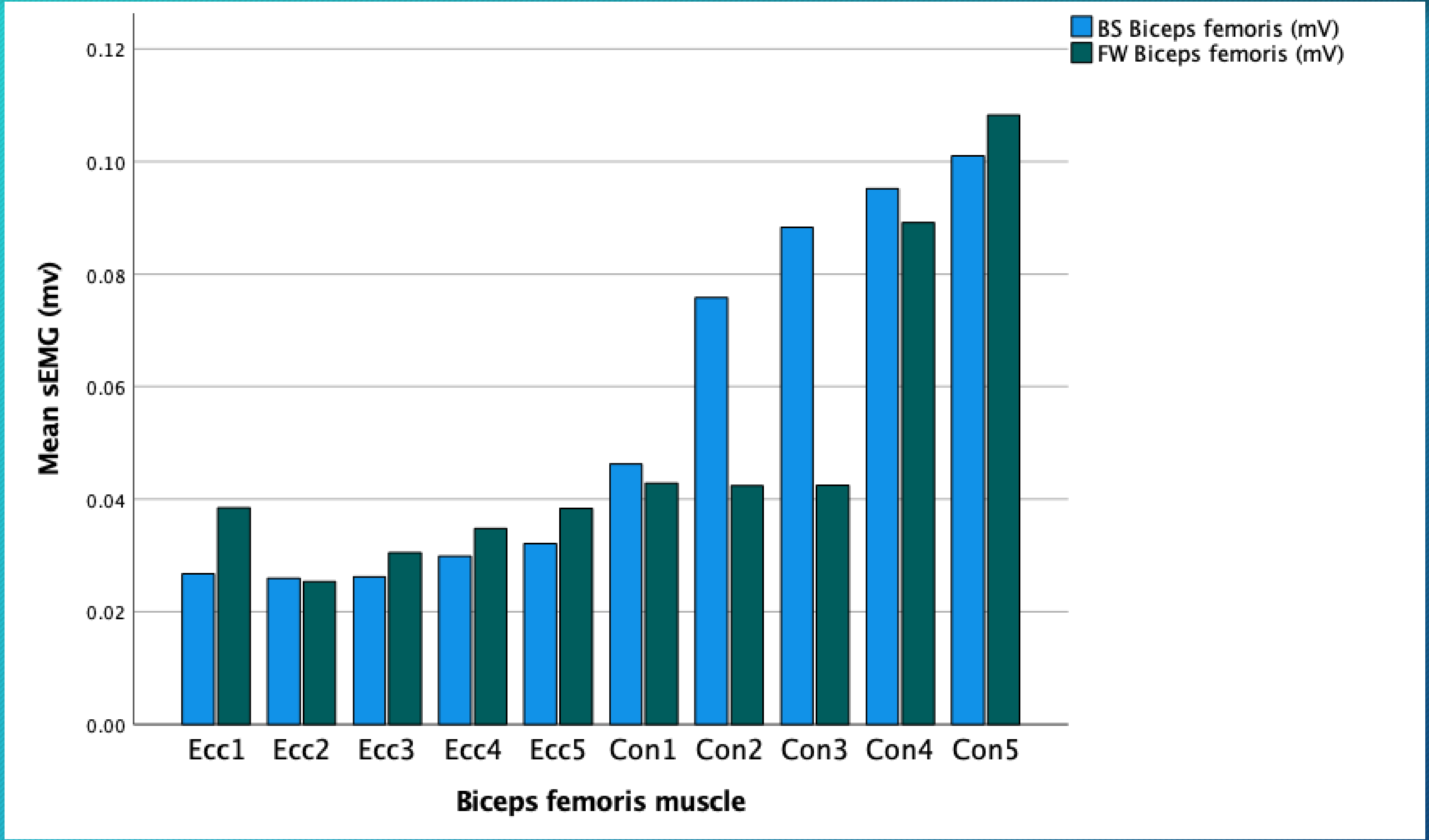
BS Vastus lateralis (mV)
FW Vastus lateralis (mV)
0.3
0.2
0.1
0.0
Mean sEMG (mv)
Ecc1
Ecc2
Ecc3
Ecc4
Ecc5
Con1
Con2
Con3
Con4
Con5
Vastus lateralis muscle

Results



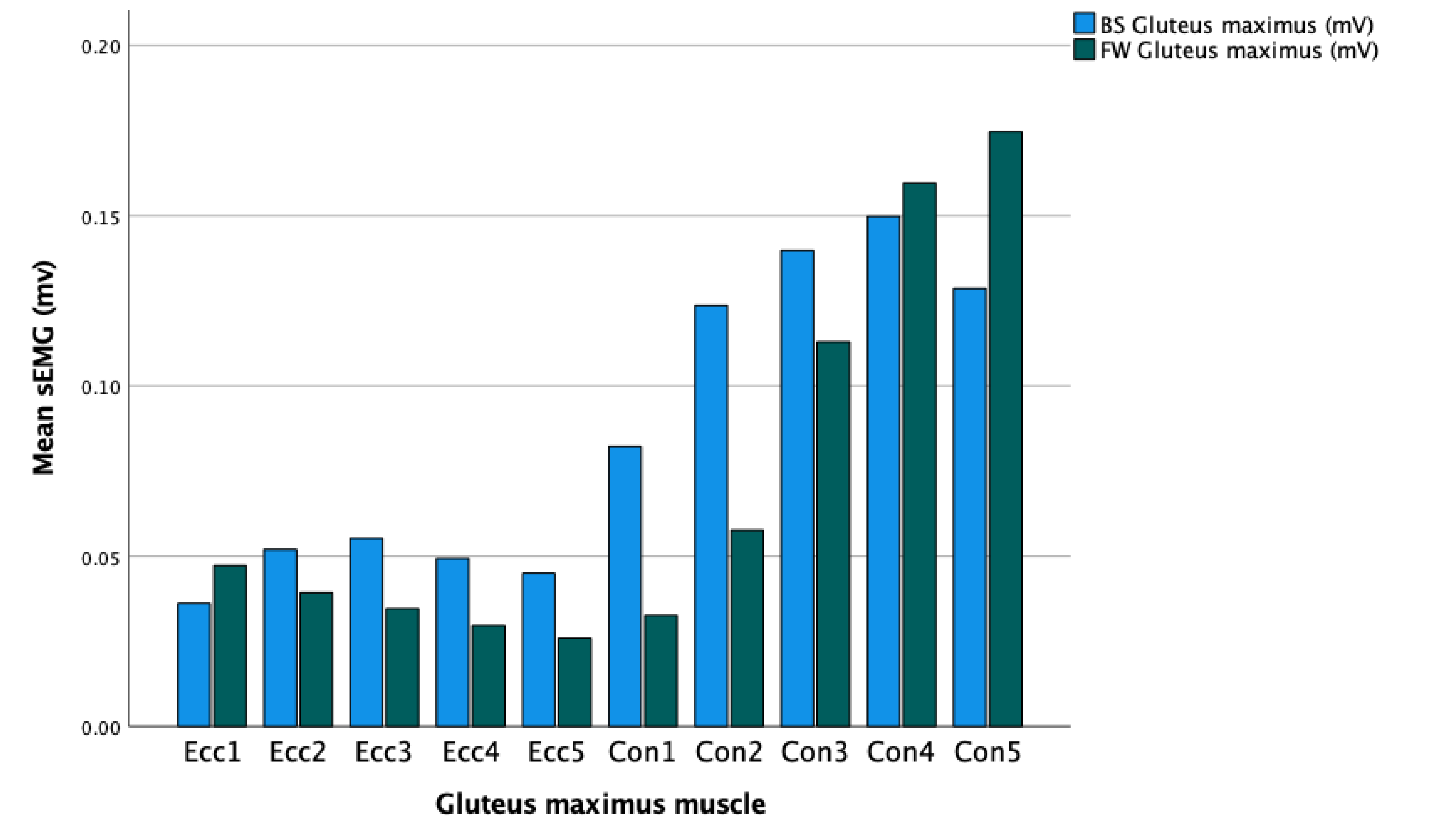
BS Vastus medialis (mV)
FW Vastus medialis (mV)
Mean sEMG (mv)
0.4
0.3
0.2
0.1
0.0
Ecc1
Ecc2
Ecc3
Ecc4
Ecc5
Con1
Con2
Con3
Con4
Con5
Vastus medialis muscle

Results



BS Biceps femoris (mV)
FW Biceps femoris (mV)
Mean sEMG (mv)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Ecc1
Ecc2
Ecc3
Ecc4
Ecc5
Con1
Con2
Con3
Con4
Con5
Biceps femoris muscle

Results



BS Gluteus maximus (mV)
FW Gluteus maximus (mV)
Mean sEMG (mv)
0.20
0.15
0.10
0.05
0.00
Ecc1
Ecc2
Ecc3
Ecc4
Ecc5
Con1
Con2
Con3
Con4
Con5
Gluteus maximus muscle

Results

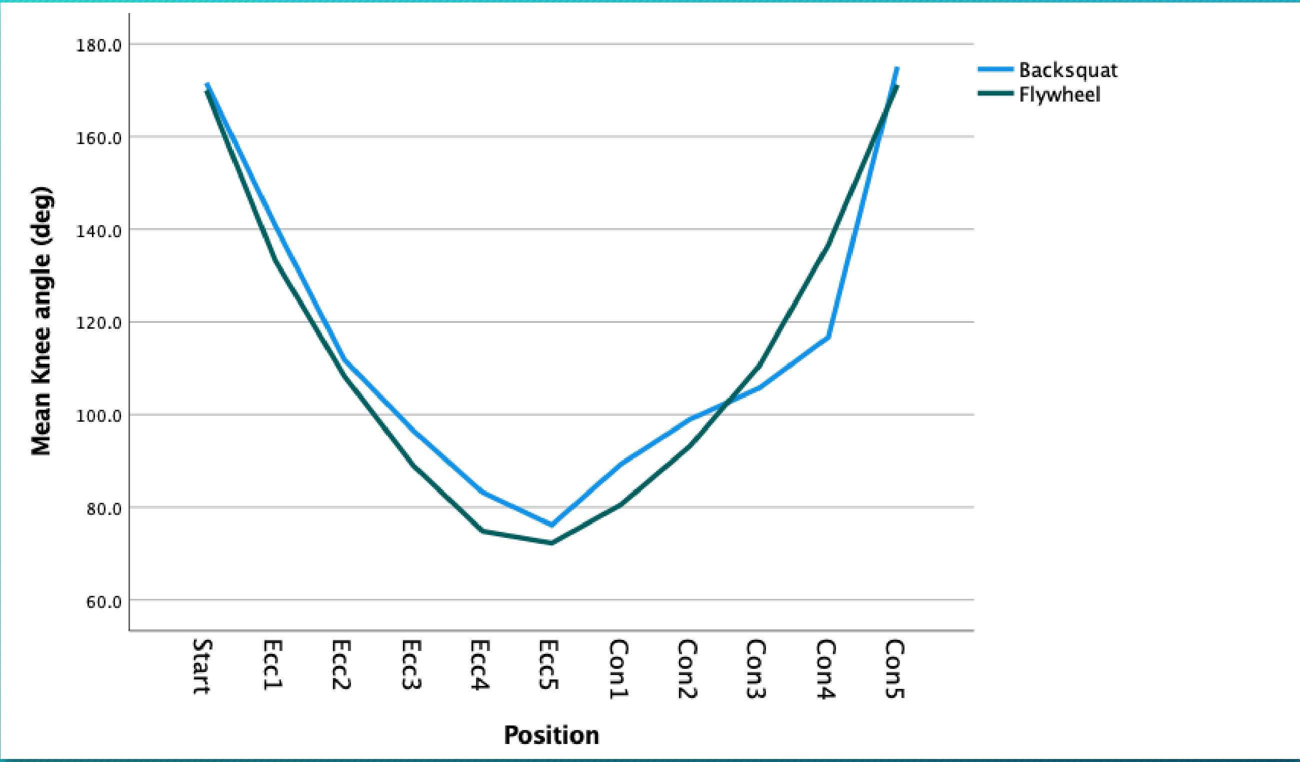
Position	Rectus femoris	Vastus lateralis	Vastus medialis	Biceps femoris	Gluteus maximus
Full repetition	25.5 % 31.9% *	1.6 % 2.9 %	2.1 % 6.7 %	10.6 % 9.0 %	15.2% * 9.8 %
Eccentric	16.6 % 24.5 %	11.7 % 16.4% *	11.5 % 17.7 %	17.2% * 17.3% *	26.1% ** 19.8% *
Concentric	24.2 % 29.2 %	5.4 % 6.8% *	5.4 % 2.3 %	22.3 % 20.0 %	11.3 % 6.2 %

Position	Rectus femoris	Vastus lateralis	Vastus medialis	Biceps femoris	Gluteus maximus
Ecc1	66.1 % 67.5 %	28.0 % 37.1% *	35.2% * 42.8% *	35.6 % 39.0% *	28.9 % 35.3 %
Ecc2	57.0 % 62.3 %	4.5 % 13.9 %	22.6 % 28.2 %	2.3 % 6.3 %	24.1% * 15.4 %
Ecc3	22.6 % 27.1 %	18.6 % 23.1% *	23.9 % 29.3 %	15.0 % 15.3 %	43.4% * 32.6% *
Ecc4	20.1 % 18.0 %	6.3 % 9.5 %	0.6 % 2.5 %	15.3 % 18.2 %	46.0% ** 43.4% **
Ecc5	13.8 % 32.0 %	10.4 % 12.4 %	2.9 % 12.3% *	17.7% * 14.6 %	49.8% * 50.3% *
Con1	19.2 % 29.9 %	5.9 % 1.7 %	8.1 % 13.3 %	7.7 % 10.4 %	82.9% * 79.5% *
Con2	27.8% * 26.3 %	7.9 % 6.3 %	5.0 % 9.1 %	56.5% ** 60.4% **	69.0% * 63.2% *
Con3	38.3 % 43.0 %	2.1 % 2.5 %	11.0 % 5.4 %	70.1% ** 59.2% *	18.2 % 12.7% *
Con4	24.2 % 30.9 %	13.7% * 14.2% *	11.6 % 11.8 %	6.5 % 8.3 %	8.0 % 14.6% *
Con5	75.8% * 66.8% *	43.8% ** 44.4% **	34.8% * 38.1% *	6.9 % 12.7 %	35.9 % 38.7 %

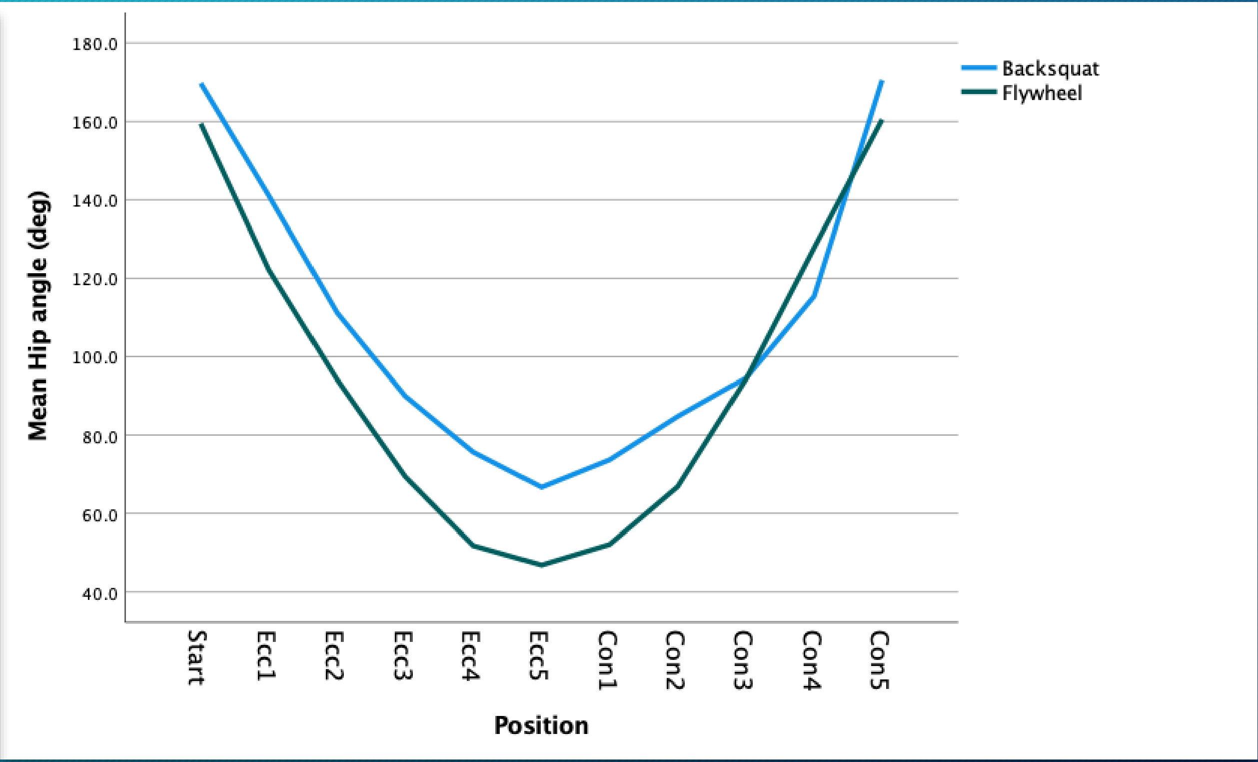
Top value = Duration matched squats
Bottom value = Force matched squats
Greater activation in BS
Greater activation in FW

* Significance p < 0.05
** Significance p < 0.001

Results



Mean Knee angle (deg)
180.0
160.0
140.0
120.0
100.0
80.0
60.0
Start
Ecc1
Ecc2
Ecc3
Ecc4
Ecc5
Con1
Con2
Con3
Con4
Con5
Position
Backsquat
Flywheel



Mean Hip angle (deg)
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
Start
Ecc1
Ecc2
Ecc3
Ecc4
Ecc5
Con1
Con2
Con3
Con4
Con5
Position
Backsquat
Flywheel

Results

Position	Statistics	BS Knee angular velocity (deg/s)	FW Knee angular velocity (deg/s)	% - Difference	BS Hip angular velocity (deg/s)	FW Hip angular velocity (deg/s)	% - Difference
Eccentric	Mean	**-54.0**	**-52.3**	**3.2 %**	**-58.0**	**-59.4**	**2.3 %**
	Std. Deviation	17.3	15.1	-	18.1	12.7	-
Concentric	Mean	**47.2**	**53.1**	**11.7 %**	**49.6**	**61.0**	**20.8% ***
	Std. Deviation	14.1	9.3	-	15.9	9.5	-
Ecc1	Mean	**-84.7**	**-98.1**	**14.7 %**	**-77.6**	**-98.0**	**23.3% ***
	Std. Deviation	35.5	39.1	-	27.0	30.8	-
Ecc2	Mean	**-81.9**	**-65.9**	**21.7% ***	**-84.6**	**-74.0**	**13.4 %**
	Std. Deviation	27.5	16.9	-	26.7	18.9	-
Ecc3	Mean	**-43.3**	**-51.2**	**16.9 %**	**-61.7**	**-64.1**	**3.8 %**
	Std. Deviation	21.6	17.2	-	30.2	21.1	-
Ecc4	Mean	**-40.0**	**-39.9**	**0.4 %**	**-40.8**	**-47.8**	**16.0 %**
	Std. Deviation	31.9	27.8	-	28.7	23.0	-
Ecc5	Mean	**-20.1**	**-6.3**	**104.2% ***	**-25.6**	**-13.0**	**65.6% ***
	Std. Deviation	18.0	7.6	-	16.0	8.8	-
Con1	Mean	**31.0**	**22.5**	**31.7% ***	**16.0**	**14.2**	**11.7 %**
	Std. Deviation	16.5	10.2	-	15.2	9.8	-
Con2	Mean	**24.6**	**33.8**	**31.5 %**	**26.7**	**39.9**	**39.6% ***
	Std. Deviation	17.8	11.8	-	13.2	14.3	-
Con3	Mean	**15.7**	**47.0**	**99.9% ****	**21.7**	**75.0**	**110.3% ****
	Std. Deviation	7.1	14.8	-	21.8	22.7	-
Con4	Mean	**27.5**	**70.5**	**87.7% ****	**52.9**	**90.1**	**52.0% ****
	Std. Deviation	16.0	21.6	-	28.0	23.6	-
Con5	Mean	**137.3**	**91.6**	**40.0% ****	**130.5**	**85.9**	**41.1% ***
	Std. Deviation	37.6	17.3	-	43.2	18.4	-

* Significance $p < 0.05$	Greater velocity in BS
** Significance $p < 0.00$	Greater velocity in FW

Conclusion

- The main purpose of this study was to find out how does these two squatting methods differ from each other in terms of kinematics, force production and muscle activity
- Barbell BS and FW squat are both bilateral squatting methods that can be performed with maximal external loads and forces and they do look similar in outline
- Looking at the kinematics, it is safe to say that there are some major differences that can explain some of the differences in force production and muscle activity
- Greater average and peak forces in BS might be due to inexperienced subjects in regards of FW squatting and that the external load stays always constant whereas in FW squat there is a big range in terms of force throughout the squat motion due to inertia of the FW
- Muscle activity tended to be greater in FW squats, especially in the eccentric phase. This might be due to active pulling of the FW that activates the stretch reflex, creating more activity in the muscles

Conclusion

- The biggest difference in hip angles were seen in the concentric phase, where greater angles were seen in BS. This is due to the external load
- The back needs to be more upright in BS since the barbell creates greater tension in the lower back. In FW squat, where a harness is used, no external tension is created on the lower back which allows for a more forward lean in the concentric phase causing a smaller hip angle
- The biggest difference in hip and angular velocities were seen around the sticking point in the concentric phase
- In BS the motion almost stopped for a moment in the sticking point and after overcoming that accelerated again towards the end of the motion
- In FW squat the angular velocities gradually increased throughout the concentric phase with no sticking point

Conclusion

- The biggest difference is still that barbell BS uses conventional gravity-based loading and FW squats uses moment of inertia in a FW as resistance, which most likely explains the majority of the findings
- This study compared squat movements and lower limb muscle activity, but FW devices are versatile, and a lot of different movements can be done using it
- More research needs to be done with comparisons like in this study to find out what the role of FW resistance and gravity-based resistance is truly and how they differ

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