



Master thesis

Comparison of Hamstring activation during high-speed running and various hamstring strength exercises.

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SAMTYKKE TIL HØGSKOLENS BRUK AV MASTEROPPGAVE

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Preface

I would like to thank my excellent advisor Professor Roland Van den Tillaar for his support and guidance through the process with this master thesis. I will also express my gratitude to the subjects for their patient participation in this study.

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Abstrakt

Formål: Målet med denne studien var å undersøke muskelaktivitet under forskjellige hamstring styrkeøvelser, og sammenligne denne muskelaktiviteten med muskelaktiviteten under en maksimal sprint. **Forsøkspersoner:** Tolv mannlige idrettsstudenter (age 25 ± 6.2 år, 1.80 ± 7.1 m, kroppsvekt $81,1 \pm 15.6$ kg) deltok i denne studien som besto av en maksimal sprint og syv hamstring styrke øvelser. De gjennomførte en maksimal sprint og tre repetisjoner av hver øvelse. Den beste repetisjonen ble tatt med inn til statistiske analyser. **Resultater oppsummert:** Den maksimale sprint hastigheten var 22.48 ± 2.03 km/h, Signifikante forskjeller I EMG aktivitet for Gluteus maximus, Semitendinosus, Semimembranosus og Biceps femoris ble funnet. **Konklusjon:** Dette er en av de første studiene til og undersøke EMG aktivering I hamstring under høy hastighets sprint og hamstring styrke øvelser. Men på grunn av begrensninger ved metode og utstyrsbruk, er det ikke mulig og komme opp med en konklusjon som viser hvilken øvelse som er den beste. Denne studien viser at liggende hamstring spark er den beste øvelsen, men flere studier på denne typen hamstring øvelser er nødvendig før en uttalelse om hvilken øvelse man skal trene for å motvirke skader i sprint.

Nøkkelord: EMG, muskel aktivitet, styrke, trening, hamstring, sprint, skader

Abstract

Purpose: The aim of this study was to examine the muscles activity during different hamstring strengthening exercises and compare the activity to the activation during a maximal sprint. **Subjects:** Twelve male sports students (age 25 ± 6.2 years, 1.80 ± 7.1 m, body mass $81,1 \pm 15.6$ kg) participated in the study consisting of a maximal sprint and seven hamstring strength exercises. They performed one maximal sprint and three repetitions of each exercise. Only the best repetition was taken in for statistical analyses. **Main results:** The maximal sprint velocity was 22.48 ± 2.03 km/h, significant differences in EMG activity for the Gluteus Maximus, Semitendinosus, Semimembranosus and Biceps femoris were found. **Conclusion:** This is one of the first studies to examine EMG activation in the hamstring muscle group during high-speed sprint, and hamstring strengthening exercises. However, due to limitations from methodology issues and insufficient equipment, it is not possible to come up with a conclusion about which exercise is the best. This study shows that the laying hamstring kick is the best, but more studies with more hamstrings strength exercise are needed before making a statement about what hamstrings strength exercise is the best for sprinting.

Keywords: EMG, muscle activity, training, strength, hamstring, sprint, injuries

1.Introduction

1.1Introduction

Hamstring strain injuries are one of the most frequently occurring injuries in sports, representing approximately 12-24% of all athletic injuries (Ebben, 2009) (Woods, et al., 2004) (Schmitt, Tyler, & Mchugh, 2012). Hamstring strain injuries have a high tendency in many sports, including soccer (Ekstrand & Gillquist, 1983) (Inkelaar, 1994), Australian football (orchard, 2011), American football (Elliot, Zarins, Powell, & Kenneyon, 2011) and sprinting. High-speed running is the common point between these activities and account for the majority of hamstring strains (Guex & Millet, 2013).

This high speed running is a cyclic movement, which can be divided in two main separate phases: the stance and the swing phase. The stance phase begins when the foot comes in contact with the ground and when the toes leaves the ground it marks the end of the stance and the beginning of the swing phase. These two main phases can again be divided in several phases, which makes it easier to explain when the hamstrings are active and why. Higashihara et al_ (2013) defined a stride as the time from ground contact of the right foot to the next contact of the same foot. To describe the relationship between the joint angles and EMG data they divided the running cycle into five different phases that are shown in figure 1. 1) early stance phase: beginning with foot strike and ending with maximum knee flexion during ground contact, 2) late stance phase: beginning with maximum knee flexion during ground contact ending with toe-off; 3) early swing phase: beginning with toe-off and ending with maximum hip-flexion; 4) middle swing phase, beginning with maximum knee flexion and ending with maximum hip flexion; and the last phase, 5) the late swing phase, beginning with maximum hip flexion and ending with the foot strike.

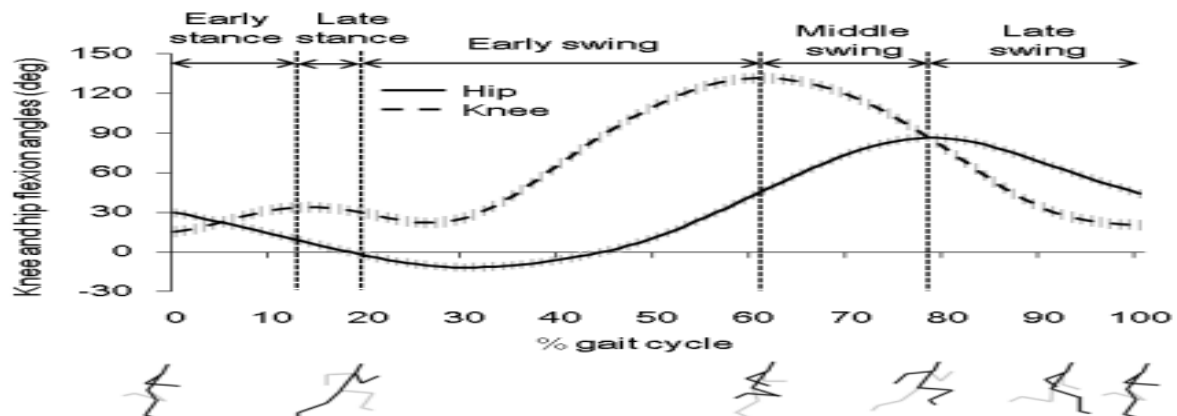


Figure 1. The running cycle, and the angles of the knee and hip. (Higashihara, Ono, Nagano, & Fukubayashi, 2013)

During these different phases the hamstring is active. The main function of the hamstring is to flex the knee and to extend the hip. However the hamstring consists of three muscles: the biceps femoris(BF) on the lateral backside of the thigh and on the medial back side, the semitendinosus(ST) and semimembranosus(SM). (Store medisinske leksikon, 2014) Due to their location on the backside and origin and insertion the three muscles have different functions. They are all responsible for the actions at the hip and knee because they cross both joints at the origins and insertion.

The Biceps femoris and semimembranosus are pennate muscles, which means they have large physiological cross-sectional areas and are more suitable for torque-production than fusiform muscles. Previous studies have reported that due to their morphological properties, the semimembranosus and biceps femoris are selectively recruited during extension of the hip to provide the muscle torque necessary for this exercise (Ono, Okuwaki, & Fukubayashi, 2011) The semitendinosus is built up with long fibres with many sarcomers in series, illustrating its potential to contract quickly over long distances. Ono et al (2010) reported that the muscle is selectively recruited during eccentric knee flexion exercise because of its morphological property of effectively dealing with strain (Ono, Okuwaki, & Fukubayashi, 2010)

All hamstring muscles cross the knee and the hip and joint thereby could bend the knee and extend the hip. Due to the lateral position the biceps femoris can also exorciate the knee. While the semitendinosus and semimembranosus are responsible for rotating the leg inward and stretching the thigh. The hamstring muscles are «angled» in its construction and consists

mainly of type 2 fibres which are designed for high speeds and large powerful activations (French, 2008).

Due to the difference in location and anatomy the three muscles have different activity patterns during the different phases of high speed running cycle. Biceps femoris shows a significantly higher activation during early stance and late swing than during the middle swing. The activation of Biceps femoris and Semimembranosus muscles during early stance was greater than during late stance phases. During the stance phase of the running cycle, the hamstring muscles activate against hip flexion and knee extension during the ground contact of the foot. With this activation the hamstrings plays an integral role in the forward propulsive force. Under a high demanding sprint, the activation demands of the Biceps femoris and Semimembranosus muscles is high before and after foot contact because of their function as hip extensors, on the other hand Semitendinosus muscle shows high activation primarily during control of knee extension during the late stance and middle swing. (Higashihara, Ono, Nagano, & Fukubayashi, 2013). Figure 2 shows the running cycle.

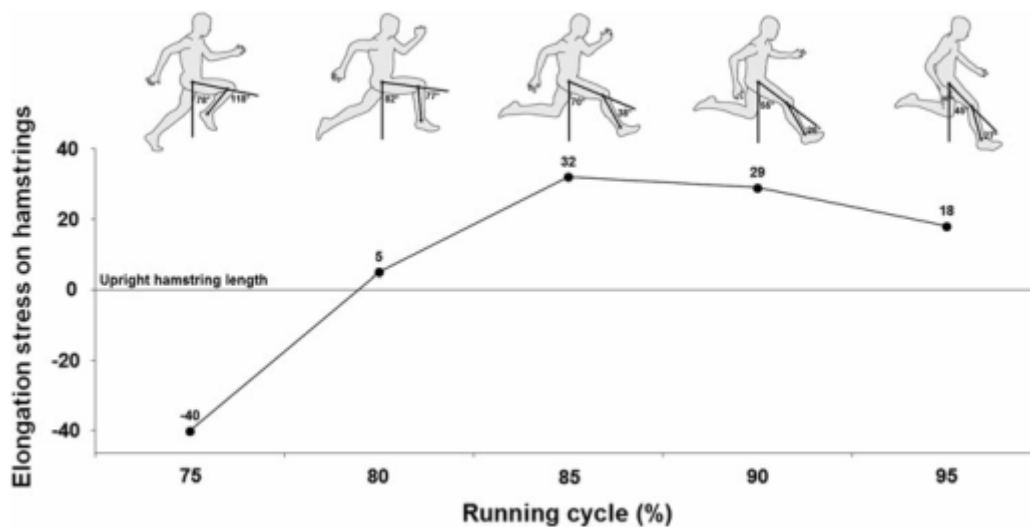


Figure 2. The running cycle, % of running cycle and how much stress the hamstring is undergoing. (Guex & Millet, 2013)

The terminal swing and the start of the stance phase have been found as main periods for hamstring strains. During sprinting the hamstring muscles eccentrically contract during the late swing and late stance phases, which make the risk of hamstring injury greatest during those phases. (Bahr & Holme, 2003) (Yu, et al., 2008). Yu et.al(2008) demonstrated that peak elongation velocity of the hamstring is higher during the late swing phase than during the late

stance phase when sprinting. They combined the results from their experiment to previous findings on the association between strain rate and where the injury occurs. They postulated that hamstring strain injuries might be most likely to occur at the muscle tendon junction during the late stance phase, and in the muscle belly during the late swing phase. (Yu, et al., 2008)

1.2 Risk Factors

As earlier mentioned, hamstring strain injuries occur during high-speed running. Several studies have identified different risk factors for these hamstring strains. These risk factors can be categorized in two categories: 1) Unmodifiable factors like age (Daly, 2013), previous hamstring injury (Engebretsen, Myklebust, Holme, Engebretsen, & Bahr, 2010) (Schmitt, Tyler, & Mchugh, 2012) (Daly, 2013). (Agre, 1985) and 2) modifiable factors: Hamstring weakness (Agre, 1985) (Foreman, et al., 2006), muscle fatigue (Makaruk & Makaruk, 2009), decreased flexibility (Jönhagen, 2005), poor running and poor neuromuscular control (Devlin, 2000). Engebretsen et al. (2010) showed that among all the risk factors examined, previous hamstring was the strongest risk factor for recurrent strain (Engebretsen, Myklebust, Holme, Engebretsen, & Bahr, 2010).

Since it is not possible to affect the unmodifiable factors, only the modifiable factors will be discussed further in this thesis. Hamstring weakness is one of the most common risk factors associated with hamstring injuries. It is suggested that too little strength in hamstring can produce sufficient force and counter the productive force from the quadriceps in various movements (Foreman, et al., 2006). Hamstring weakness is as stated a modifiable factor, it is suggested that a stronger muscle would provide adequate «protection» from stretching and tearing the muscle fibre (Guex & Millet, 2013).

Muscle fatigue is as well as weakness a postulated risk factor. Fatigue reduces muscle flexibility, as well as it disrupts the muscle coordination, and impairs the ability of muscle relaxation (Makaruk & Makaruk, 2009). Muscle fatigue can be connected to a variety of systems, specially the nervous system. In connection with the hamstring, it is speculated that the innervation of the two heads of the biceps femoris. When muscle innervation is disturbed there occurs a «delay» in contraction of the biceps femoris, resulting in a reduced ability to generate sufficient power, which in turn leads to an increase chance of injury (Foreman, et al., 2006). Decreased flexibility is increasing the risk for injuries and this includes the hamstring.

(Jönhagen S. , 2005) Unlike other features of motor activity, there is no intention of developing maximum output when it comes to flexibility. The athletes' level of flexibility should be optimum or allow for a slight excess in range of motion when performing an exercise (Makaruk & Makaruk, 2009). Although the factor regarding a previous hamstring strain is the most obvious one, this paper will put the focus on hamstring weakness and exercises targeting developing of hamstring strength.

1.3 Hypothesis

Several training studies were conducted to investigate how to decrease weakness and increase of neurological control. To evaluate these studies properly Guex and millet (2013) presented a conceptual framework for strengthening the hamstring and for developing specific exercises. They proposed six key parameters for developing exercises. Contraction type, Load, Range of motion, Angular velocity, uni - bilateral exercises and Kinetic chain. Guex and Millet (2013) concluded that the used hamstring strength exercises should be more specific to simulate the power upon the hamstring during the late swing phase of sprinting. Furthermore, none of the training studies directly compared the hamstring activity during the different strength training exercises and the activity during the sprint phase, which makes it difficult to state if the muscle training is specific enough for high speed running. At present information is limited regarding which resistance training maximally activates the hamstring, which exercise that is the most specific and which exercise that targets the hamstrings strength on the most vulnerable spot: the late swing phase. Training the hamstring muscle group is critical for performance and plays an important role in hamstring injury prevention. Some of the chosen exercises for this study are from several of existing papers focusing on hamstring exercises. In addition, we have made some adjustments to some of the exercises, and included some less known exercises. The exercises also got the focus on targeting the hamstring in a lengthen state, a normal state which the hamstring undergoes in the running cycle. The exercises are also doable without any specific equipment, though it is an advantage to perform the exercises with a partner.

Therefore, the aim of this study is to examine different hamstring exercises and compare the EMG activity in the hamstring muscle group during the various exercise and a maximal sprint. Nordic hamstring has shown in other studies to be a very tough exercise. We have made some "improvements" on the Nordic hamstring exercise, which we think will put the hamstring under more stress (Nordic hamstring with return, and Nordic hamstring with bump

exercise). We also included some new exercises that we think will stress the hamstring in a more specific way; more similar to the running cycle. It is hypothesised that the sprint, which is known as the major reason for hamstring injury will be high on activation. It is hypothesised that laying hamstring kick mimics the sprint in a lengthen state; the standing kick mimics the sprint for the knee angles. Therefore are these exercises compared with the Nordic hamstring and hamstring cranes that are performed with bended knee's, which could influence the muscle activation differently.

2. Materials and methods

2.1. Subjects

Twelve male sports students (age 25 ± 6.2 years, 1.80 ± 7.1 m, body mass $81,1\pm 15.6$ kg) participated in the study. Participants were excluded from the study if they had a former hamstring strain (the previous year, before testing), or if they had muscular pain, illness that could reduce their effort to produce maximum power under each exercise. All participants were familiar with training the lower parts of the body. The participants were asked to refrain from any heavy strengthening training targeting the lower body during the 48 hours before testing. This to ensure they were free from strains and in good shape. Ethics approval was obtained from the local research ethics committee. (REK, 2015)

2.2 Methodology

This study compared maximal integrated electromyography (I-EMG) values for the hamstring muscle group and the Gluteus maximus, during a maximal sprint and different types of hamstring strength exercises. All data sampling were collected during a single test session/test day with a randomized exercise order. On a separate day before the actual testing day, all subjects were familiarized with the test procedures performing a pre-test; testing out the exercises without the equipment (EMG/camera). On the day of testing the subjects were first briefed on the exercise order. Secondly: hamstring area of the right leg were shaved for hair, making the preparation phase faster, this will be further described later. After shaving the leg, the subjects participated in a general warm up (15min on treadmill; wood way curve, Waukesha, Usa) and a personal warm up (stretching, or more running if

needed) for 5 min. Following the warm-up, the subjects were allowed 5 minutes of rest, where they were allowed to drink water and go to the toilet if needed. During this rest, reflective markers were placed on anatomical landmarks shown in figure 3b. In addition, the subjects' skin was prepped for surface electrode placement. This skin preparation included three stages; 1) shaving hair, 2) removing dead skin from the surface with a razorblade, and 3) cleaning the surface with alcohol (figure 3a).

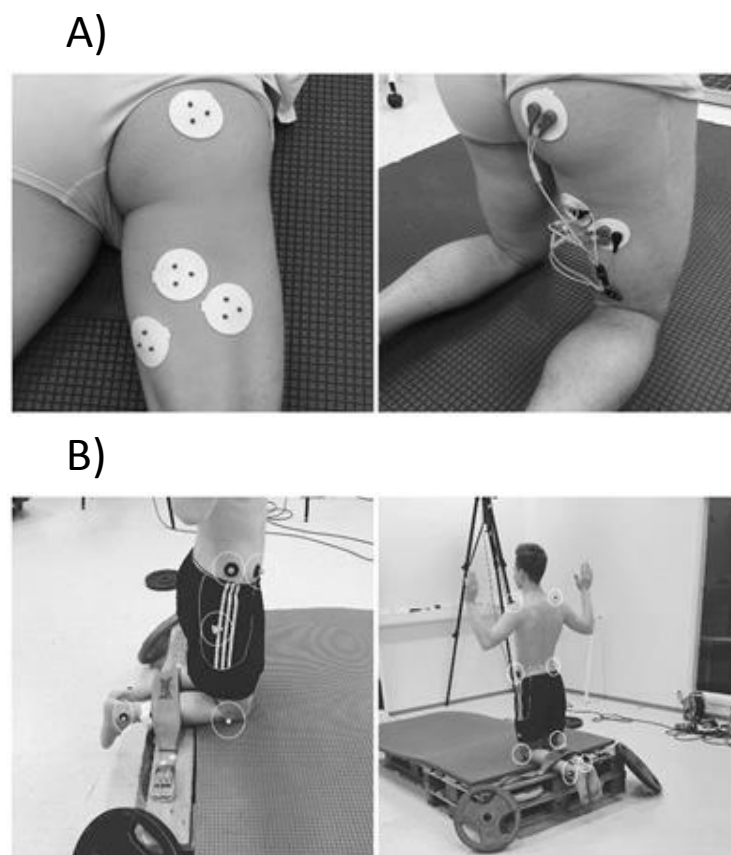


Figure 3: a) Surface electrode placements, on the hamstring and gluteus maximus and b) Qtm marker placements: shoulders, hips, trochanter major, knees, ankles.

The test consisted of a maximal sprint and seven strengthening exercises. The sprint were conducted on a wood way curve treadmill, the strength exercises included the; the laying hamstring kick, the standing hamstring kick, Nordic hamstring, Nordic hamstring with return, Nordic hamstring + bump, Hamstring cranes without return, and the Hamstring cranes with return exercise (Figure 5). All subjects performed the maximal sprint before doing the

exercises, the laying hamstring kick exercise was always performed the last. The reason for this was mostly for practical reasons, Figure 3 shows the platform construction where they performed the exercises. The order of the exercise was then randomized. Figure 4 shows the first subject's test order. A non-motorized treadmill was used for the warm up and the maximal sprint exercise. We used a wood way curve. This is a treadmill with an innovative curved running surface, which means the users are able to control their pace at will. With this treadmill, you can take out the exact highest maximal running velocity. Compared to a motorized mill, you will have to turn the speed up and up, and jump off. With the wood way curve, you just run as fast as you can then calm down. This treadmill I also used by all of the clubs in the National Football league (NFL) (Woodway, 2015). Limiting the test to three repetitions per exercise, randomization of the exercise order, and 5 minutes of recovery (Ebben, 2009) were provided between the exercises, to reduce fatigue and an order effect.

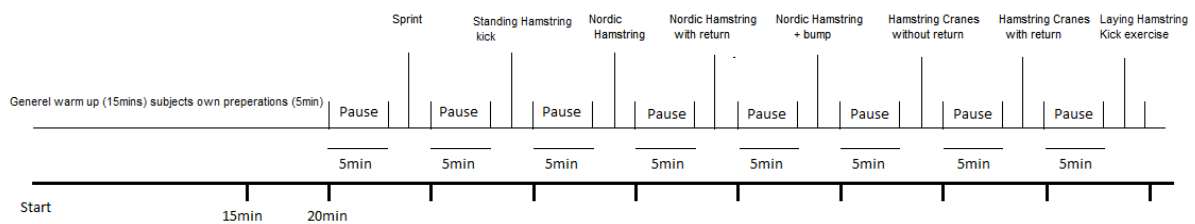


Figure 4. Timeline showing the exercise order for one of the subjects. Sprint as first, and laying hamstring kick as last. Rest of the exercise order were randomized.



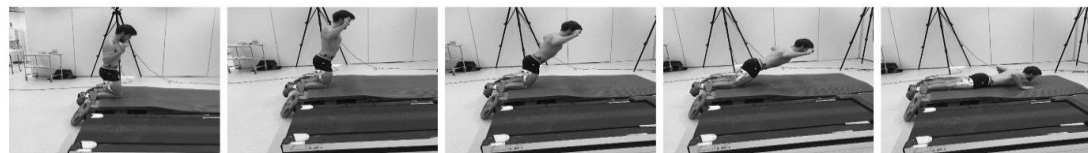
Maximal sprint (Curve)



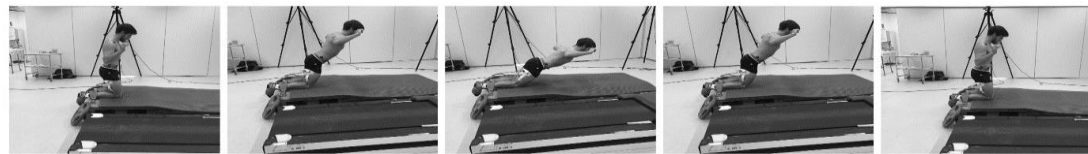
Laying hamstring kick



Standing hamstring kick



Nordic Hamstring



Nordic hamstring with return



Nordic hamstring with bump



Hamstring cranes



Hamstring cranes with return

Figur 5: The sprint on the curve and the different hamstring training exercises.

2.3 Data collection

Electromyography (EMG) was used to quantify muscle activity during the various exercises. Before the initial testing, the skin of the subject was shaved with a hand razor and carefully cleaned with ethanol to reduce impedance. To strengthen the signals, conducting gel was applied to each electrode. EMG surface electrode was attached on the lower part of the back right foot. They were placed on the muscle belly of the biceps femoris, semitendinosus, semimembranosus and the gluteus maximus. EMG activity was measured with Muscledlab (Ergotest Technology AS, Langesund, Norway). The raw EMG signals, sampled at 1000Hz were amplified and filtered using a preamplifier located as close to the pickup point as possible. The signals were high pass and low pass (600, 8 Hz) filtered, rectified, integrated and converted to root-mean-square (RMS) signals using a hardware circuit network (frequency response 450 kHz, averaging constant 12 ms, total error $\pm 0.5\%$). With a common rejection rate of 106 dB, the RMS signals were re-sampled at a rate of 100 Hz using a 16 bit A/D converter (Tilaar & Saeterbakken, 2014).

All EMG data were filtered and collected as RMS signals. As in this study, a comparison of muscle activation during the various exercises is investigated in relation to the maximal EMG activity during a maximal sprint. The RMS data were taken out as raw maximal activation data and calculated/transformed into percentage of the maximum activation. The maximal activation in this study was the sprint (100%). An example can be that the biceps femoris had a maximal activation of 793 RMS in the sprint, and 388RMS In Nordic hamstring exercise, in this case $793\text{RMS} = 100\%$ activation, and 388RMS will be 48,91% of the maximum.

Three-dimensional positions of the joints and limb segments were measured using a motion capture system (Qualysis, Gothenburg, Sweden) with six cameras (500 Hz) that tracked the position of the reflective markers (2.6 cm in diameter) placed on the following anatomical landmarks on both sides of the body: the hips, the knees and at the ankle part of the foot. The cameras were used to assess the angles of the hips and knee joints during the sprint and various exercises.

2.4 Statistical analysis

To assess differences in kinematics and EMG activity during the sprint and the 7 exercises, a One-way ANOVA with repeated measures for each of 4 muscles was used. If the sphericity assumption was violated the greenhouse-Geisser adjustments of the P values were reported in

the results. Post hoc test using Holm-bonferroni probabilities adjustment was used to locate significant differences. The level of significance was set at $p \leq 0.05$. For statistical analysis purposes, the SPSS Statistics v21 (SPSS, Inc., Chicago, IL) was applied. All results are presented as means \pm standard deviations and effect size was evaluated with (Eta partial squared) where $0.01 < \eta^2 < 0.06$ constitutes a small effect, a medium effect when $0.06 < \eta^2 < 0.14$ and a large effect when $\eta^2 > 0.14$ (Cohen, 1988).

3. Results

3.1 EMG

The maximal sprint velocity was $22,48 \pm 2,03$ km/t, Significant differences in EMG activity for the Gluteus maximus ($F_{1,6,17,8} = 24.1$, $p < 0.001$, $\eta^2 = 0.68$), Semitendinosus ($F_{2,3,23,5} = 9.28$, $p < 0.001$, $\eta^2 = 0.48$), Semimembranosus ($F_{2,8,31,5} = 14.1$, $p < 0.001$, $\eta^2 = 0,56$) and Biceps femoris ($F_{2,2,24,8} = 47.45$, $p < 0.001$, $\eta^2 = 0.81$) were found. Post hoc comparison showed that the maximum EMG activity during sprinting was significantly higher with all other exercises for the Semitendinosus and biceps femoris (figure 6), while for the other two muscles (gluteus and Semimembranosus) this was the same except from the EMG activity in the laying kick, which was not significantly different from the sprints (Figure 7)

In addition, for the gluteus maximus it was found that the maximal EMG activity for the laying hamstring kick exercise was significantly higher with all other hamstrings strength exercises and EMG activity of the standing kick was significantly higher than the Nordic bump exercise (Figure 6). EMG activity of the laying kick was also significantly higher for the semimembranosus with standing kick and the two cranes exercises (Figure 7).

For the semitendinosus and biceps femoris the maximal EMG activity with the cranes and the cranes with return were significantly lower than the three different Nordic hamstrings exercises (Figure 6). For the semimembranosus only the EMG activity of the cranes were significantly lower than the three Nordic hamstrings exercises (Figure 6).

3.2 Angles

The angles at the hip and knee for the different muscles showed significant differences for the Gluteus Maximus hip ($F_{3,2,28,8}=7.484$, $P < 0,001$, $\eta^2 = 0,45$), Gluteus maximus knee ($F_{3,7,33,0}=2,884$, $P < 0,041$, $\eta^2 = 0,243$), Semimembranosus hip ($F_{2,7,21,8}=19.115$, $p < 0,000$, $\eta^2=0,705$), Semimembranosus knee ($F_{2,5,20,0}=4.35$, $p < 0.021$, $\eta^2= 0,350$), Semitendinosus hip ($F_{3,0,18,07}=15.53$, $p < 0,001$, $\eta^2=0.721$), Semitendinosus knee ($F_{2,2,15,5}=5.24$, $p < 0.016$, $\eta^2=0.428$) Biceps femoris hip ($F_{2,6,18,6}=18.54$, $p < 0.001$, $\eta^2=0,726$) and for the Biceps femoris knee ($F_{2,9,20,4}=13.2$, $p < 0.001$, $\eta^2=0,654$)

Post hoc comparison showed that the angles for the hips and knees were similar between the sprint and the standing hamstring kick for all the muscles (figure 8, 9, 10, 11). The angles were also similar for the Nordic hamstring exercises, there were only significant differences between Nordic hamstring with bump; and Nordic hamstring and Nordic hamstring with return for the semitendinosus knee (figure 11b). The angles were also similar between the hamstring cranes exercise. There were only a significant difference between the cranes exercises for the semimembranosus (figure 10b).

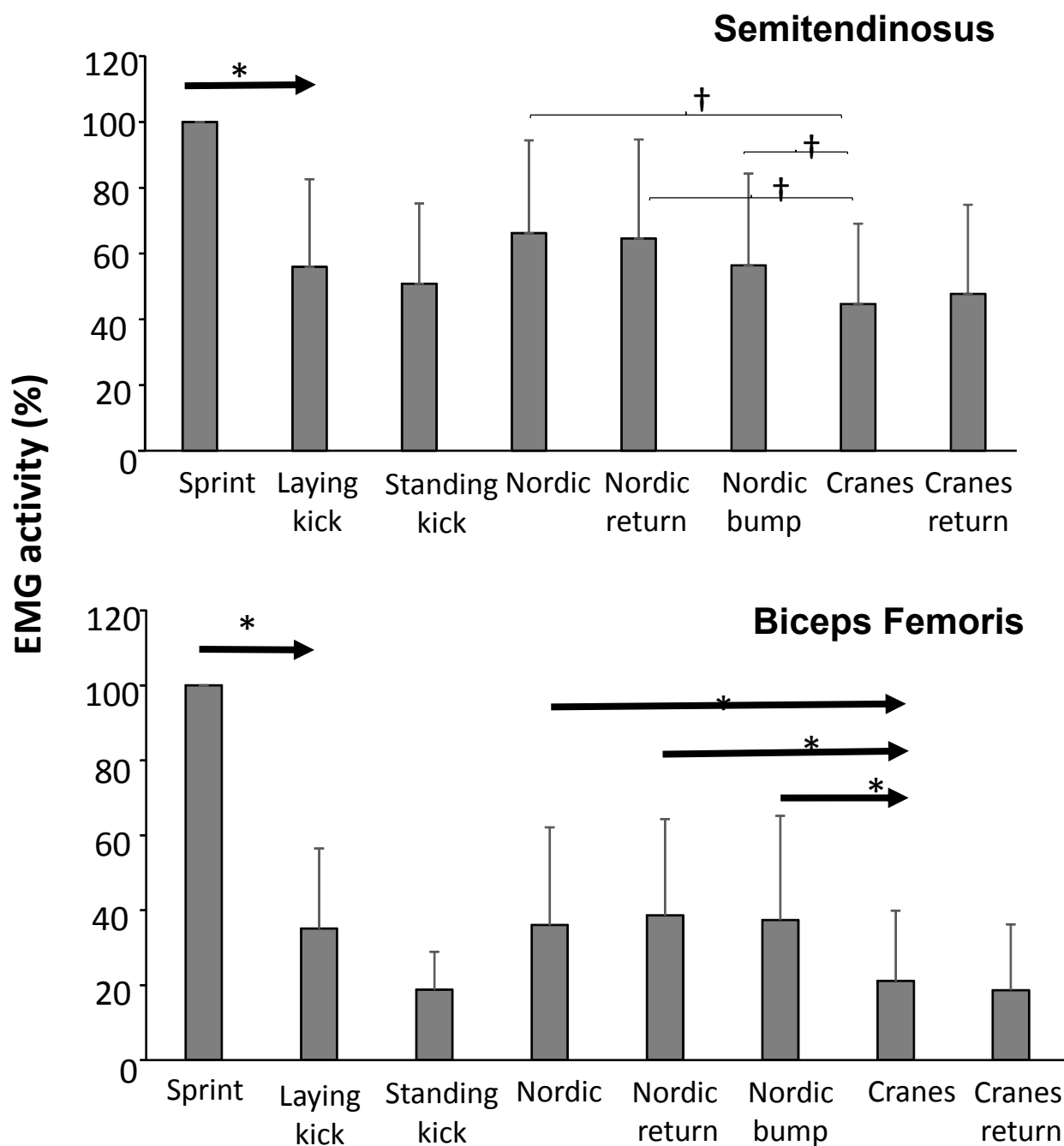


Figure 6.

Maximum activity for Semitendinosus and Biceps femoris EMG at the different exercises (%) related to the sprint exercise (100%).

* Indicated a significant difference between this EMG activity and all right from the arrow on a $p < 0.05$ level.

† indicates a significant difference in EMG activity between these two exercises on a $p < 0.05$ level

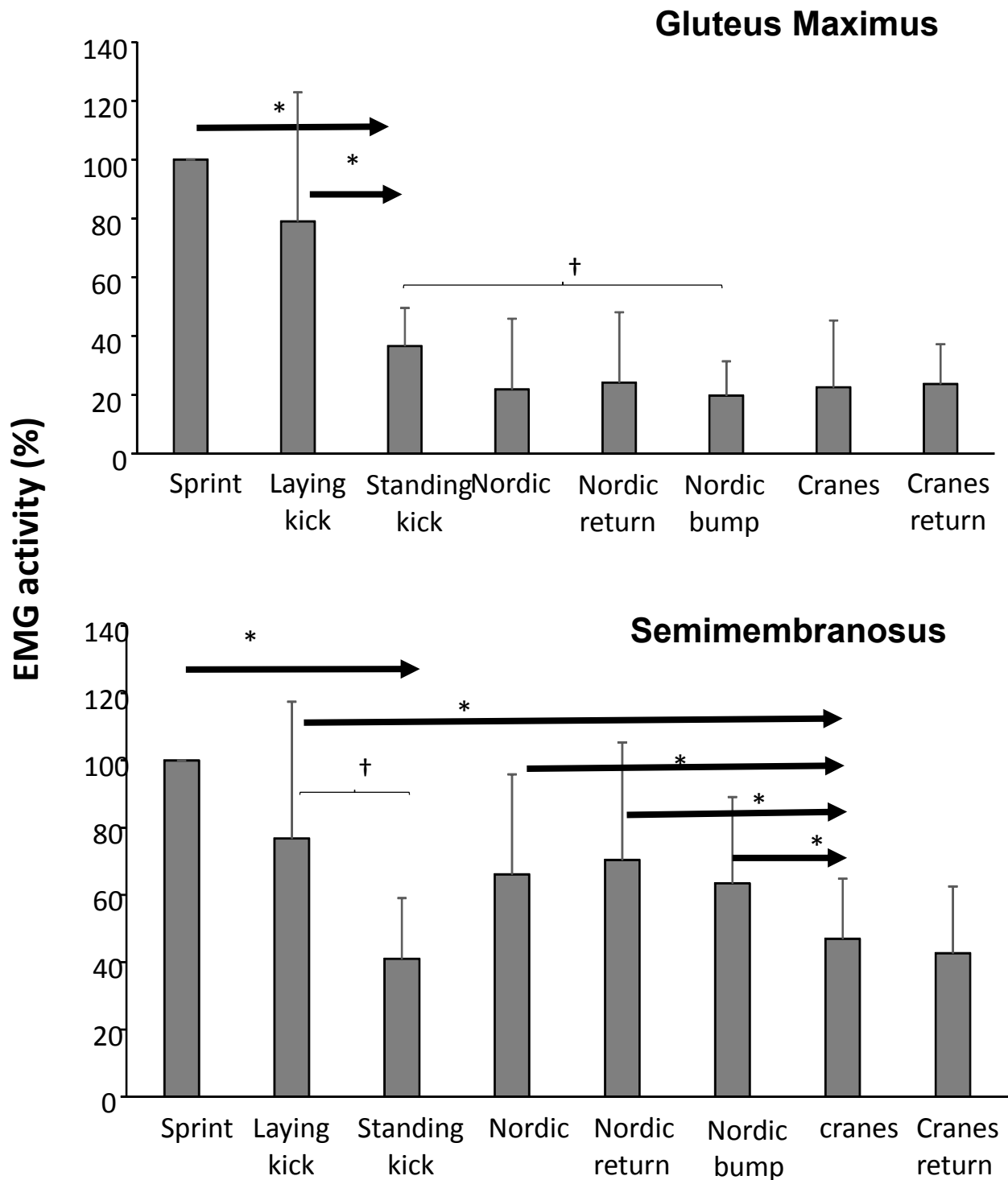


Figure 7.

Showing maximum for gluteus maximus and semimembranosus EMG activity at the different exercises (%) related to the sprint exercise (100%).

* Indicated a significant difference between this EMG activity and all right from the arrow on a $p < 0.05$ level.

† indicates a significant difference in EMG activity between these two exercises on a $p < 0.05$ level.

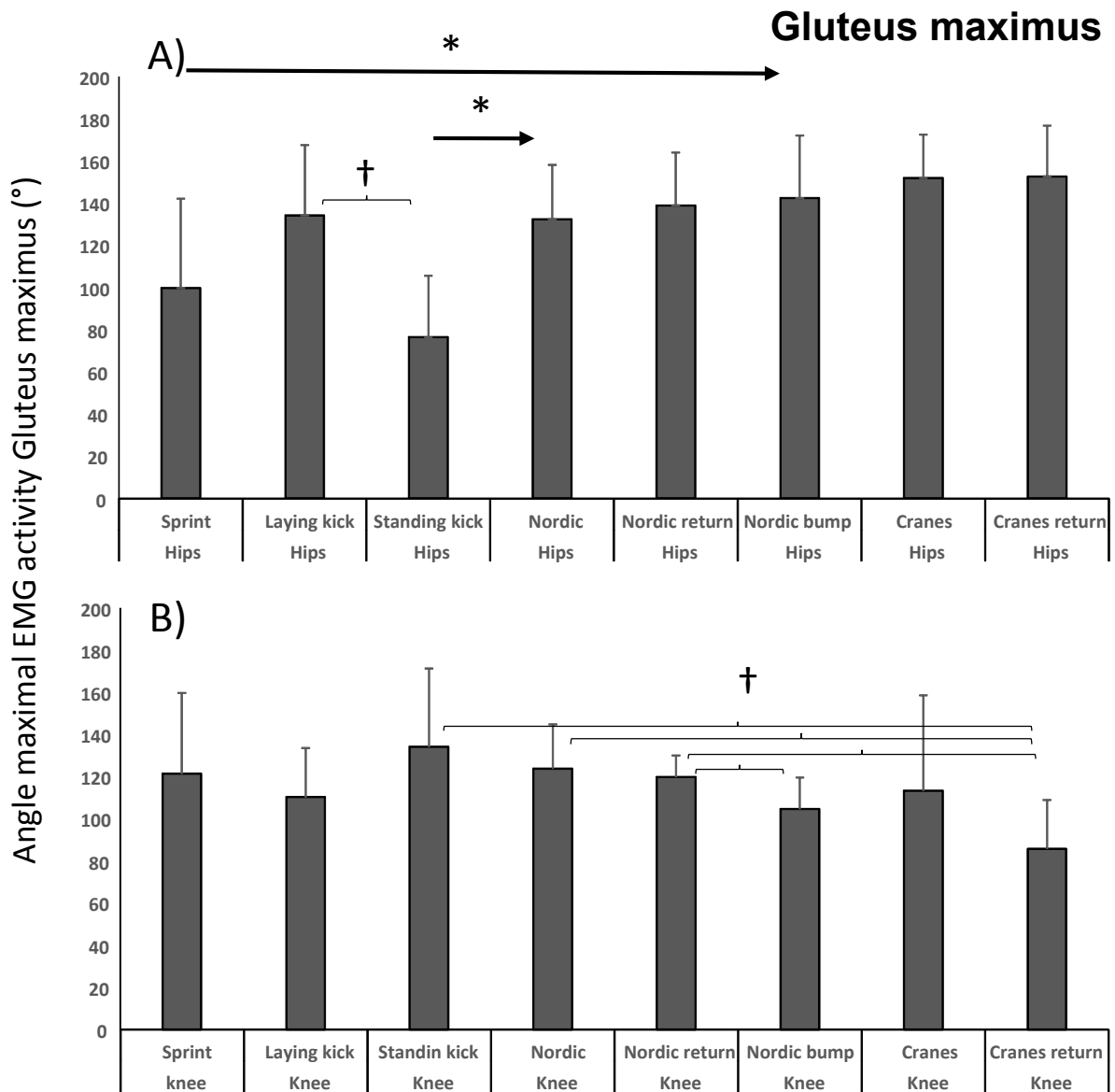


Figure 8. Showing the angles for Gluteus maximus at maximal EMG activity.

* indicates a significant difference between this variable and all right from the sign on a $p < 0.05$ level.

† Indicates a significant difference between these two variables on a $p < 0.05$ level.

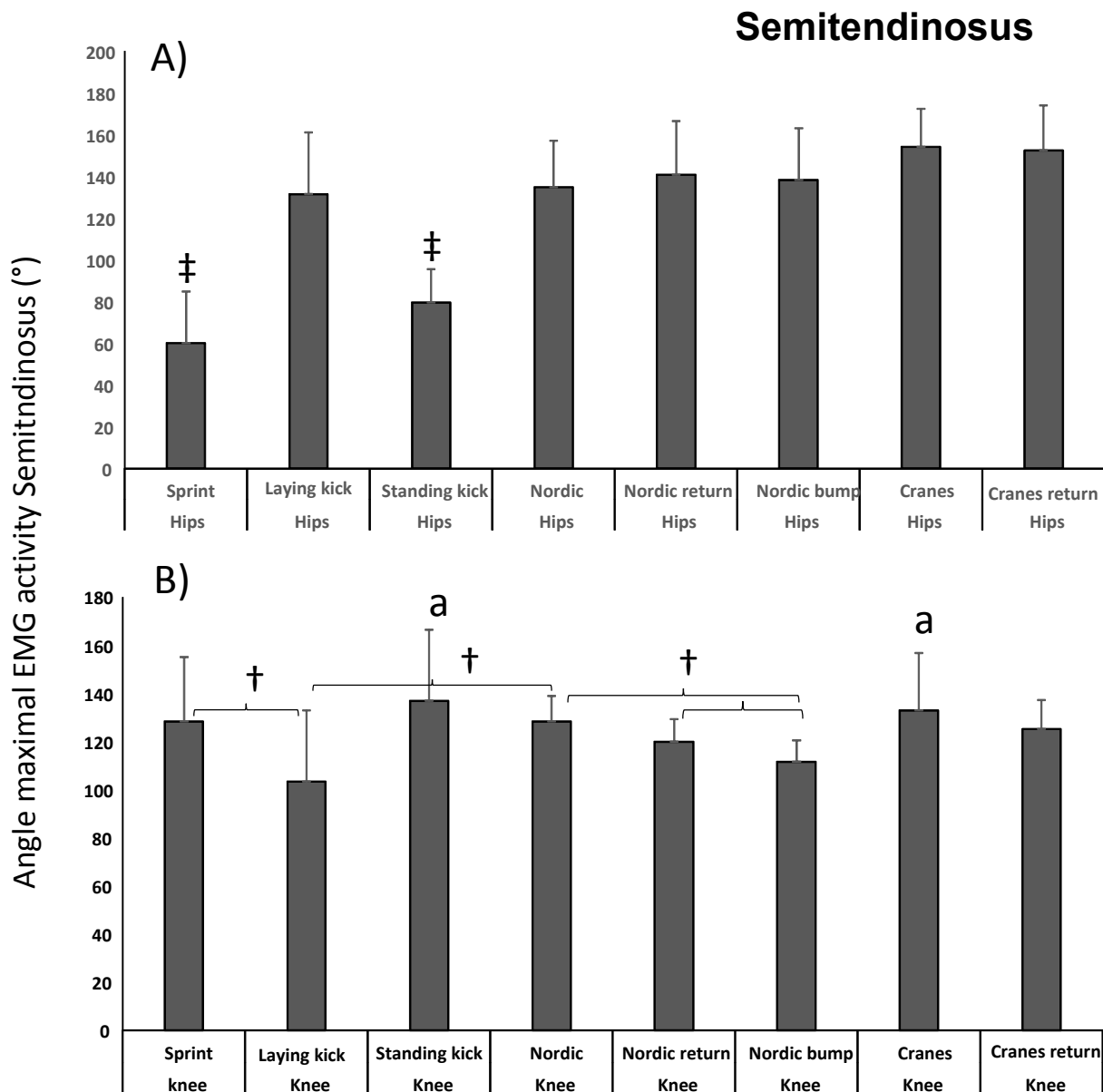


Figure 9. The angles for the A) hip and B) knee joint at maximal EMG activity for the semitendinosus.

‡ indicates a significant difference in angle with all other exercises except sprint/standing kick

a indicates significant difference in angle with all other exercises except with sprint and standing kick/cranes on a $p < 0.05$ level.

† Indicates a significant difference between these two variables on a $p < 0.05$ level.

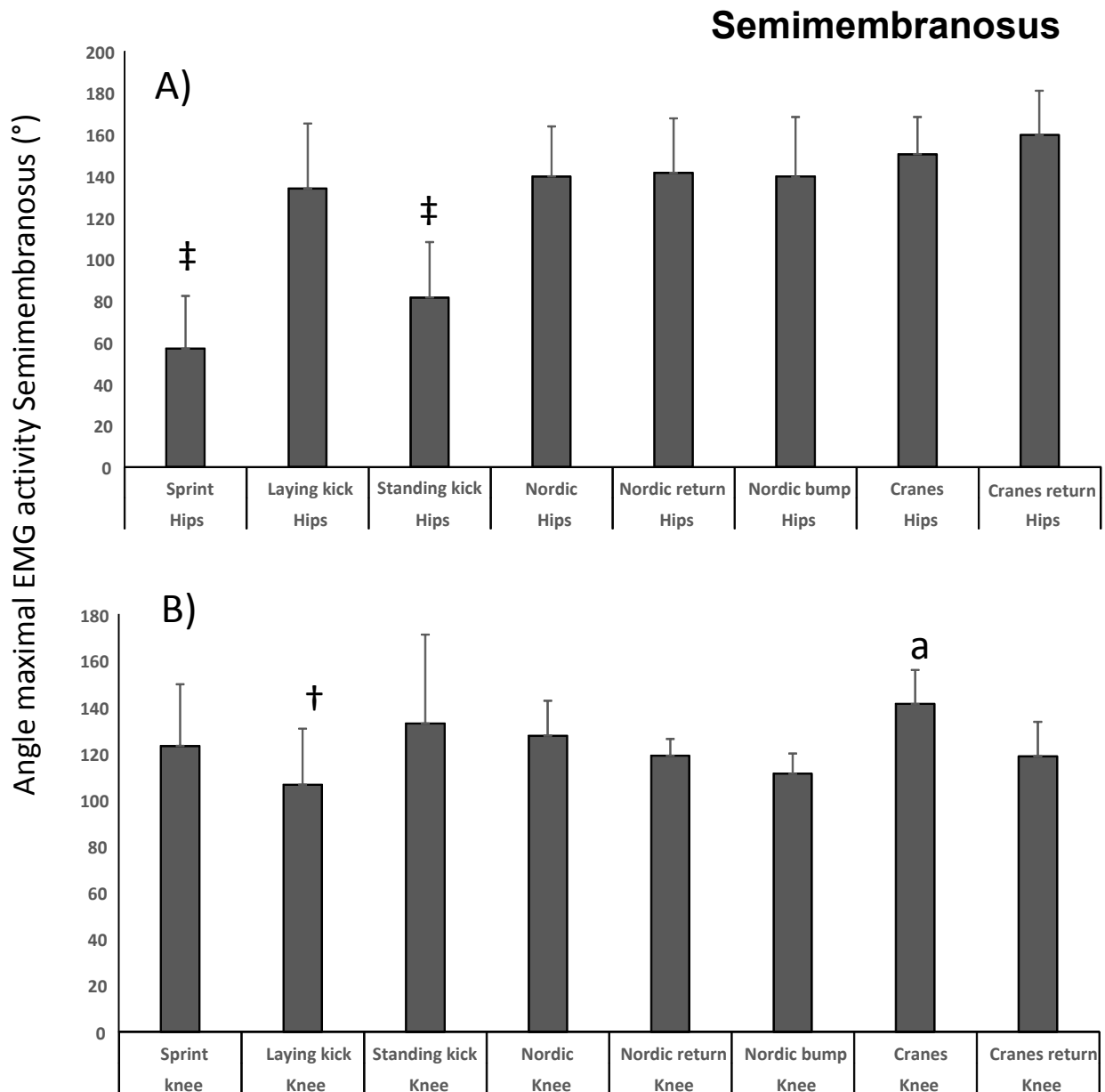


Figure 10. The angles for the A) hip and B) knee joint at maximal EMG activity for the semimembranosus.

‡ indicates a significant difference for this variable with all other variables except sprint/standing kick on a $p < 0.05$ level.

† Indicates a significant difference between this exercises and all exercises except nordic bump and crane return on a $p < 0.05$ level.

a indicates significant difference in angle with all other exercises except with sprint and standing kick

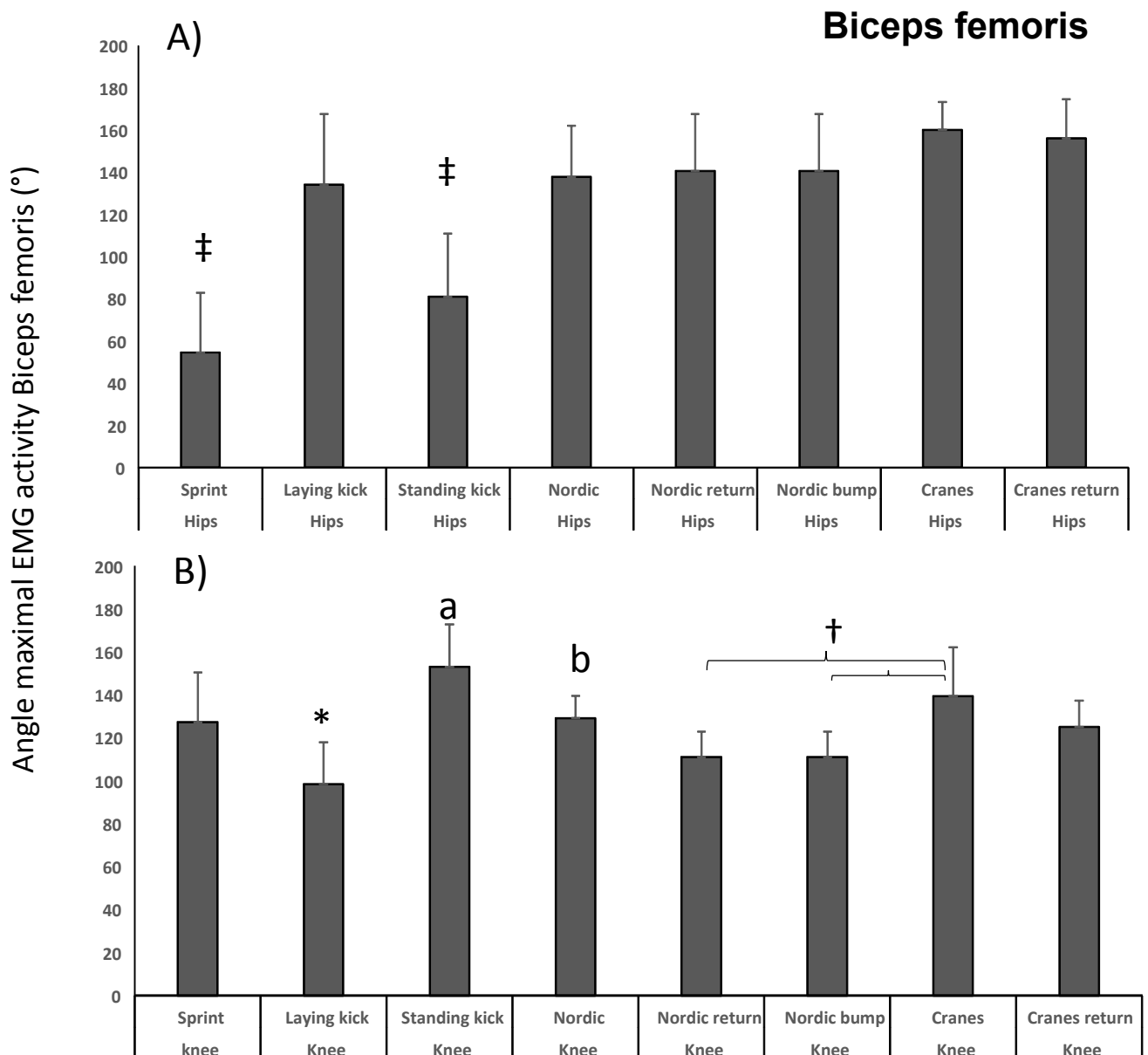


Figure 11. Showing the angles for biceps femoris at maximal EMG activity.

† Indicates a significant difference between this exercise and all variables except sprint/standing kick on a $p < 0.05$ level.

* Indicates a significant difference between this exercise and all others on a $p < 0.05$ level.

a Indicates a significant difference between this exercise and all others except cranes on a $p < 0.05$ level.

b Indicates a significant difference between this exercise and all others except sprint and cranes on a $p < 0.05$ level.

† Indicates a significant difference between these two variables on a $p < 0.05$ level.

4. Discussion

The aim of this study was to examine the muscles activity during different hamstring strengthening exercises, and compare the activity to the activation during a maximal sprint. The main findings of this investigation can be summarized as followed: 1) it demonstrated that there are significant differences in activation within the four muscles when comparing the sprint and all the hamstrings strength exercises. 2) the laying hamstring kick was the exercise with highest overall activation. 3) the standing hamstring kick was the exercise with the lowest overall activation.

Analyses of hamstring activation reveals that the maximal sprint resulted in the highest muscle activity, for the semitendinosus and biceps femoris. For the semimembranosus and gluteus Maximus the sprint was significantly higher than all exercises except the laying hamstring kick. This was expected since the high-speed sprint is the activity, which often results in hamstring strain and injuries. In a sprint cycle, the hamstring undergo a stretch-shortening cycle, with a lengthening state occurring during terminal swing phase and a shortening phase occurring right before foot strike, this continues throughout stance phase. (Schache, Dorn, Blanch, & Brown, 2012) This stretch shortening cycle puts the hamstring under high intensity pressure. Chumanov Et al (2011) showed that during high speed running the hamstring are almost constantly active and act concentrically and eccentrically pulling the legs up through stance and to slow the forward moving limb at the end of the swing phase. (Chumanov, Heiderscheit, & Thelen, 2011) Most studies have measured EMG activity to evaluate hamstring muscle function during sprint. For example, studies involving recording of EMG activity have found the hamstring to be active from mid swing phase until terminal stance. (Chumanov, Heiderscheit, & Thelen, 2011) (Higashihara, Ono, Nagano, & Fukubayashi, 2013) (jönhagen, Ericson, Nêmeth, & Eriksson, 1996) Some studies have reported peak activity to occur during stance phase (jönhagen, Ericson, Nêmeth, & Eriksson, 1996), and some studies have reported peak activity to occur during the terminal swing (Chumanov, Heiderscheit, & Thelen, 2011) (Higashihara, Ono, Nagano, & Fukubayashi, 2013). This present study show that the sprint had an average RMS for the Gluteus maximus: 259, Semitendinosus:378, Semimembranosus:594 and Biceps femoris: 503. The average angles at the hip and knee for maximal activation for the Gluteus maximus was at 99° and 124°. The average angles at the hip and knee for maximal activation for the Semitendinosus

was at 60° and 128°. For the Semimembranosus the average angles at the hip and knee for maximal activation was 57° and 123°, the average angles at the hip and knee for maximal activation for the Biceps femoris was at 61° and 127°. This study shows that the gluteus maximus is most active right before and under foot strike. Biceps femoris is more active through and throughout stance phase. Semitendinosus is more active in the late swing phase, and the Semimembranosus is more active in the late stance phase/early swing. This correlates both with those studies that show that the stance phase and those studies that shows that the swing phase is the most precarious ones. In this study we used a wood way curve treadmill, which got a curved running surface. This might be something to consider when examining EMG activity on the hamstring muscles. Since the running cycle will be shorter, the foot strike will come faster because of the construction of the mill, in comparison with a normal treadmill and normal surface you will not be able to fully stretch your knee. This can be one of the explanations of why the muscle activity shows to be higher under stance then in the late swing phase as some studies have shown.

When comparing the sprint with the hamstring strength exercises, we calculated the maximal RMS for the strength exercise into percentage of the sprint, since sprint then was 100%. The strength exercise with the highest overall activation was the laying hamstring kick. The muscle activation for the muscles varied from 35-79% of max (sprint100%), the biceps femoris was the lowest with 35% of max, semitendinosus had 55%, semimembranosus had 76% and gluteus maximus was the highest with 79% of max activation. The angles of the hip and knee varied from each muscle. The angles of the hip varied from 131-134°, and the angles of the knee varied from 98-110°. The kinematics for this exercise (dynamic and fast motion) is far from the kinematic pattern in the Nordic and cranes hamstring exercises, which are slow eccentric exercises. In comparison the Nordic hamstring exercise which is a commonly used exercise in hamstring strain prevention programs showed to be lower than the laying hamstring kick, but significant different from the hamstring crane exercises. The average muscle activation for the Nordic hamstring exercise varied from 21-66% of the maximal activation shown in the sprint. The gluteus maximus was the lowest with 21%, biceps femoris 36%, and semitendinosus and semimembranosus had the same with 66%. The angles of the hip and knee varied from each muscle. The angles of the hip varied from 132°-139° and the angles of the knee varied from 124°-129°. On forehand we thought that the modified Nordic hamstring exercises would stress the hamstring more than the original one; 1) because in the Nordic hamstring with return exercise you first put the hamstring under pressure in a eccentric

phase, before pulling the body back again with a concentric contraction. 2) the nordic hamstring with bump, got the same motion as the Nordic-return, only with a barbell which hypothesised would give more stress. There were no significant differences between the exercises. When it comes to the standing hamstring kick, we thought this exercise would be high on EMG activity since the exercise mimic the sprint in a certain way. It's a powerful exercise with a lot of speed in it. The subject's opinion after the testing was that the exercise was a bit pain to perform. Although the exercise felt hard it was the lowest exercise on EMG activity. It scores lowest on maximal activation for the gluteus maximus, semimembranosus and biceps femoris, only 36, 41 and 18% of maximal activation compared to the sprint. Only the semitendinosus was at 50% of maximal, only 5% lower than the laying kick. But the angles were more similar compared with the sprint than any other exercise. So one of the exercise hypothesised to mimic the sprint the most, was actually the exercise with lowest total activation.

Determining muscle activity from EMG data can be a difficult process, especially for fast dynamic activities such as sprinting. This because many factors influence the relation that may exist between the EMG signal and the force developed by a muscle. This is not limited but it includes muscle length, muscle fatigue, contraction type and elastic properties of the muscle (Disselhorst-klug, Scmitz-rodé, & Rau, 2009). The risk of crosstalk between the muscles can never be entirely avoided, especially with muscles that are as close as the hamstring group. Also using a wood way curve treadmill with a curved running surface might or would influence the running kinematics because the running stride will be shorter. When testing EMG activity it is perhaps an advantage to pick subjects with experience of training the specific muscle group.

Conclusion

This is one of the first studies to examine EMG activation in the hamstring muscle group during high-speed sprint, and comparing it with hamstring strengthening exercises. However, due to limitations from methodology issues and insufficient equipment, it is not possible to come up with a conclusion about which exercise that is the best. The laying hamstring exercise was the exercise with the highest activation in this study, but we don't know if it works in a training session because there are no studies that have used this exercise. While for the Nordic hamstring exercise who also show some similarities with sprinting but much lower than the laying kick, has shown in training sessions that it works in the prevention of

hamstring strain injuries. Future studies should perhaps include more exercise than this study, and even more EMG measurements (Quadriceps muscles) due to the quadriceps/hamstrings ratio, which was not included in this paper. The gained information from this study could help both future researches, coaches and athletes in the understanding of the importance of hamstring strength training. Since it is not clear yet which exercise that are the most specific in activation compared to the sprint, it is not possible to come with a recommendation. More studies have to be conducted on this field before coming up with a statement of which specific exercise you should focus on to avoid future hamstring strain injuries.

5.Referanser

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