

## MUSCLE ACTIVITY DURING THE DROP PUNT KICK

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**ABSTRACT (*J Sports Sci* 1999, 17(10):837-838)**

Punt kicking is a primary technique in Australian Rules football and Gaelic football and a secondary technique used by specific positional players in Rugby Union, Rugby League, soccer and American Football. Four professional Australian Football League (AFL) players were filmed performing six right-foot and six left-foot drop punt kicks whilst electromyograms of seven muscle groups (bilateral quadriceps, hamstrings and gluteals and rectus abdominus) were obtained with surface electrodes. The kicking motion was divided into the phases of (1) run-up/approach, (2) backswing, (3) wind-up, (4) forward swing, (5) follow through and (6) recovery. Punt kicking is a throw-like motion, with much of the work performed eccentrically in the early phases by proximal muscle groups and the resulting momentum transferred to distal segments just before ball contact. The most active muscle group studied was the quadriceps of the kicking leg, which acted eccentrically in the wind-up phase and then concentrically in the forward swing. The hamstrings of the kicking leg concentrically initiated the backswing and showed variable eccentric activity during the follow through. There was little difference between EMG profiles for right- and left-foot kicks. High activities in the kicking leg's quadriceps, stance leg's gluteal, rectus abdominus and both hamstrings help explain the high rates of muscular injuries in the AFL. The results are similar to previous findings in soccer kicking (Bollens *et al.*, 1987: In *Biomechanics X-A*, edited by B. Johansson, pp. 283-288. Champaign, IL: Human Kinetics).

## INTRODUCTION

Australian Football is one of the country's most popular spectator and participant sports, but the biomechanics of its techniques have not been extensively studied, perhaps because the sport is not played internationally. The most important means of ball progression is kicking and the drop punt is the standard kicking technique in most situations, due to a combination of accuracy, distance and speed of execution. Punting is also a primary technique in Gaelic football and a secondary technique used by specific positional players in rugby union, soccer and American football. Therefore, some relevant research has included a study of the kinematics of punt kicking (Putnam, 1991) and electromyography of the soccer kick (Bollens, De Proft & Clarys, 1987).

The most common injuries in the Australian Football League (AFL) are hamstring strains, knee injuries and groin injuries. Most injuries are equally distributed between sides of the body, although quadriceps strains are more common on the dominant kicking side (Orchard, Wood, Seward & Broad, 1998). Hamstring, quadriceps and groin injuries occur more commonly than in Australia's other football codes (Seward, Orchard, Hazard & Collinson, 1993). Factors that may explain the relatively higher incidence of hamstring and groin injuries include greater distance of sprinting during average effort, the less predictable flight of the ball, greater length of the playing arena, repetitive loads in kicking and longer duration of games. Kicking almost certainly increases the rate of quadriceps strains. It is hoped that a knowledge of when the muscle groups are working in the kicking cycle will help to explain this unique injury pattern of Australian Football and ultimately lead to injury prevention.

The aims of this study are to examine the kinematics of the drop punt kick and the role of major lower limb muscle groups in powering the kick.

## METHODS

### Subjects

Four professional AFL players were recruited as subjects (after two other players had been used as pilots). All four final subjects were right foot dominant.

### The Kicking Task

Each subject was filmed while performing six right-foot and six left-foot drop punt kicks. The players were running in to kick on a hard surface and therefore wore their club issue Puma running shoes. They were instructed to kick a football to an imaginary target 40m straight ahead of them.

### Measurement and Analysis of Lower Limb Kinematics

A two dimensional analysis of the lower limb kinematics was undertaken. Each subject was filmed in the sagittal plane using a high speed NAC video camera operating at 200 frames/second.

An array of 17 retroreflective markers was placed on each subject (Table 1). The limb closer to the camera (which had more markers) was the kicking foot in half of each of the left-foot and right-foot trials. The array of markers defined the limb segments, joint centres and local coordinate axis systems. After acquiring the video data the coordinates of each marker were digitised using the BIOVISION system (UNSW, Sydney). Every fourth frame was digitised, resulting in an effective sampling rate of 50 Hz.

Ground reaction forces were measured on the stance leg during the kick. The acquisition of video and force platform data were synchronised. Data sets consisting of the time histories of marker coordinates and ground reaction forces were used to calculate the dynamics of the lower limbs during each kick. An inverse dynamics approach was used. The analysis was undertaken using programs developed 'in-house' with ASYST.

### Measurement and Analysis of Electromyography (EMG)

Surface EMG of major muscle groups was acquired using a Flexcomp system (Thought Technology, Montreal). The electrodes were amplified at the source and connected to the receiver which was worn around the subject's waist and connected to the data acquisition system by a fibre optic cable. The EMG data was acquired at a sampling rate of 1000 Hz. After acquisition it was filtered with a dual pass fourth order digital low pass Butterworth filter with a cut-off frequency of 15 Hz. The input impedance of the electrode units is 1,000,000 M $\Omega$  and the Common Mode Rejection Ratio over 20-500 Hz is greater than 130 dB.

Seven channels of EMG data were acquired, ie. right hamstring, left hamstring, right quadriceps, left quadriceps, right gluteal, left gluteal and rectus abdominus muscle groups. A foot switch was attached to the heel of the non-kicking leg. This was used to synchronise the data with values obtained from the force platform. Initial heel contact of the non-kicking leg (which occurred near the end of the kicking leg backswing) was chosen as the point of synchronisation.

Maximum voluntary contractions (MVC) for each muscle group were obtained prior to the kicking trials. Standard muscle testing protocols were used that placed each muscle approximately at its resting length. Resistance was applied by an investigator and verbal encouragement was given. For all channels and each subject the isometric MVCs were less than the amplitude of the conditioned EMG signal obtained during the kicking trials. For the purposes of analysis the conditioned EMG signals were expressed as a percentage of the maxima recorded during the kick.

### **Examination of Relationship between Kinematics and Muscle Activation.**

Kinematic results were examined and the kicking motion for each subject was divided into six phases using hip and knee joint angles, and the position of the ball. The average EMG activity for each muscle group in each phase was pooled for the right-foot and left-foot kicks of each player. The timing of each phase for the EMG signal was determined by correlating heelstrike on the foot switch channel ( $t=0$ ) with the kinematic and kinetic output.

The relationships between muscle activation, as indicated by EMG, and lower kinematics were examined qualitatively. The type of muscle contraction, isometric, eccentric or concentric, was interpreted based on an examination of the direction of the angular motion of the appropriate joint. For example, if the knee was extending and hamstrings were active, this was interpreted as eccentric hamstrings contraction. The effect of muscle force moments applied by two joint muscles can confound this method of interpretation.

## **RESULTS**

The phases of kicking were divided up as follows: (a) Run-up and approach; (b) Backswing; (c) Wind-up; (d) Forward swing; (e) Follow-through; (f) Recovery. All phases are named with respect to the kicking foot, with (a) being a pre-swing phase, (b), (c) and (d) being the swing phases before ball contact and (e) and (f) the swing phases after ball contact. The phases are shown diagrammatically in figure 1. The following section describes these phases in detail for a right foot kick.

### **(a) Run-up and approach (finishes – R foot toe off)**

A six to eight step approach was used. Kinematic and EMG activity in this phase appeared to be consistent with normal running, which has been previously described (Mann, Moran & Dougherty, 1986). This phase was considered to finish with toe-off of the right leg. The last 0.2 seconds of the approach was designated the push-off period, in which the right hamstring sustained a strong concentric contraction to commence the backswing. The ball was held during the run-up by both hands and released by the left hand before the push-off and then by the right hand at the end of the approach. The left arm was abducted during the remainder of the motion to balance the body. The progression of the ball after release was downward (due to gravity) and forward (due to maintenance of momentum from the hand carrying it), which has been previously described by Hay (1993).

### **(b) Backswing (starts – R foot toe off; finishes – R hip maximum extension)**

Backswing started with both feet off the ground and finished when the right hip was fully extended, lasting approximately 0.1 seconds. Left foot contact generally occurred near the end of the backswing. Initial stance contact of the left foot was with the heel in three subjects and the forefoot in the other. The activity of the right hamstring started to reduce in the backswing and the left gluteal was active to coincide with left leg support.

### **(c) Wind-up (starts – R hip maximum extension; finishes – R knee maximum flexion)**

The wind-up phase was characterised by right hip flexion and right knee flexion and also lasted approximately 0.1 seconds. The hip flexion was initiated and was continued for the remainder of the kicking motion, whilst the knee flexed to wind itself up for a rapid extension during the next phase. Although the right knee was still flexing, the right quadriceps took over from the hamstring as the most active muscle group. Presuming that all quadriceps muscles were active at this time, the right rectus femoris assisted the hip flexors with this motion, while the other quadriceps muscles were performing an eccentric contraction to decelerate knee flexion and initiate the forward swing.

### **(d) Forward swing (starts – R knee maximum flexion; finishes – initial ball contact)**

The forward swing was a phase of continued hip flexion and rapid knee extension, which lasted approximately 0.05 seconds and was considered to finish at the time of ball contact. There was continued substantial activity of the right quadriceps during this phase and increasing activity of the rectus abdominus. At the time of ball contact, the right knee was still flexed approximately 50 degrees, the lower leg was moving forward with an angular velocity of approximately 1400 degrees per second and the right ankle was held fixed in plantar-flexion.

**(e) Follow through (starts – initial ball contact; finishes – R knee maximum extension)**

The initial follow-through was considered to last until the knee reached full extension, which was slightly less than 0.1 seconds after initial ball contact. Overall muscle activity was much lower in this phase, with two of the four subjects exhibiting a significant eccentric contraction of the right hamstring. From this study, it was not possible to determine the exact duration of ball contact, although it was less than 0.015 seconds.

**(f) Recovery (starts – R knee maximum extension; finishes – R hip maximum flexion)**

The right hip continued to flex during the recovery part of the follow-through, for approximately 0.2 seconds after the right knee had finished extending. The total apparent range of right hip movement was up to 150 degrees, over a period of 0.45 seconds. This range was only seen in two dimensions and some pelvic rotation may have contributed to this. The left hip appeared to move through less than 20 degrees over the same time period. During most kicks, the left foot left the ground during the recovery phase. Muscle activity for all groups was low during this phase.

The average EMG values for left and right foot kicks in each phase are presented in Figures 2 and 3. Error bars presented represent standard deviations between subjects. Standard deviations within subjects were generally lower except for the rectus abdominus channel, which was possibly affected by artefact with increased signal appearing late in the kicking motion possibly corresponding to compression of the electrode by the receiver. Between subjects, results were still fairly consistent with the exception of kicking-leg hamstring activity in the follow-through, which had high activity in two subjects and low activity in the other two.

## **DISCUSSION**

A study of the dynamics of kicking was undertaken using four first grade AFL players. While the number of subjects was low, the number of kicking repetitions was high. A total of 48 trials were studied.

The aim of punt kicking is to propel the ball in a forwards and upwards direction as accurately (and often as far) as possible. Momentum is transferred from the kicking foot/ankle complex to the ball when the angular velocity of the leg is at its maximum. Kicking has been called a 'throw-like' pattern of movement, in that the movement of proximal segment is initiated early with the distal segment lagging behind. Momentum is then transferred from the decelerating proximal segment to the distal segment, which undergoes a rapid acceleration (Kreighbaum & Barthels, 1996; Putnam, 1991; Robertson & Mosher, 1985).

McCrudden and Reilly (1993) have compared EMG findings in punt kicking of a soccer ball with drop kicking finding similar muscle activity. Bollens, De Proft & Clarys (1987) divided the soccer kick into six phases and measured EMG activity for six muscles in the kicking leg during these phases. They called their phases: (1) first step; (2) second step; (3) loading phase; (4) swinging phase; (5) ball impact; (6) follow-through. They found that vastus medialis and lateralis contractions were maximal during the loading phase, at which time the knee was still flexing. They called this part of the 'soccer paradox' that a substantial amount of muscle work appears to be done eccentrically during soccer kicking. This corresponds to the 'wind-up' phase in our description of punt kicking, where we also found maximal quadriceps activity.

Previous naming conventions for the various phases of kicking have been confusing as certain phases were named with respect to what the kicking leg is doing whereas others are referring to the stance leg. Our phase names refer only to the kicking leg. We prefer the terms backswing, wind-up and forward swing when describing the swing phase of kicking before ball contact, as they correctly describe the proximal to distal segment transfer of momentum. During the backswing both the thigh and leg are moving backwards (i.e. hip extending and knee flexing). The wind-up is when the thigh is moving forwards (hip flexing) but the knee is still flexing, so the leg lags behind the thigh. The forward swing is when both thigh and leg are moving forwards. The momentum built up during the wind-up is transferred to the leg, which rapidly accelerates during the forward swing.

Alexander and Holt (1974) concluded that more efficient transfer of momentum from the foot to the ball occurred when contact was made with the ankle region rather than the metatarsals. Plangenhoeft (1971) reported a case of a punter who lost distance when wearing a shoe which prevented full plantar flexion at the ankle, suggesting that this was also important with respect to efficient transfer of force. Our subjects kept

their ankle joints relatively fixed in plantar flexion during kicking which is consistent with these previous findings. Macmillan (1975) found that angular velocity of the leg determined foot velocity, which would correlate with distance kicked given efficient transfer of force. Large angular velocities of the leg are achieved by rapid extension of the knee, assisted by a more gradual flexion of the hip. The prime movers of these movements are the quadriceps muscles with the chief antagonists being the hamstrings. Theoretically the momentum imparted to the ball could be increased by increasing the tangential velocity at the foot, e.g. increasing the shank length or increasing the shank's angular velocity. The stabilisation of the ankle in plantar flexion effectively increases the shank length.

Overall the amount of activity in all muscle groups was high during kicking. In our study, muscle activity was expressed as a percentage of the maximum value recorded at any stage, rather than the maximum seen on an isometric MVC. For all muscle groups, the maximum values recorded during kicking were greater than in manual contractions. This might reflect the recruitment patterns necessary for high velocity muscle contractions, however this aspect requires investigation before further research is undertaken.

The combined EMG profile for a left-foot kick was very similar to a right-foot kick (with the sides reversed). All our subjects practised kicking with both feet but were right-foot dominant and felt more confident kicking on this side. The consistency of results between sides suggests similar muscle activation for dominant and non-dominant sides and also that the results of this experiment are reliable and reproducible. The only exception between sides was the stance gluteal muscle group, which showed considerably more activity during a right-foot kick (left gluteal) than a left-foot kick (right gluteal).

The quadriceps of the kicking leg showed much more activity than the stance leg. They were most active in the wind-up and forward swing phases, contracting eccentrically then concentrically. Quadriceps activity decreased substantially towards the end of the forward swing (ball contact). Robertson and Mosher (1985) also found that this occurred during soccer kicking. All subjects exhibited a concentric contraction of the kicking hamstring at the start of the backswing. There was a variation of hamstring activity during the follow-through, where two subjects showed minimal activity and the other two significant eccentric hamstring activity.

It is possible that the kicking set-up of our trials caused less eccentric hamstring activity during the follow-through phase than would be expected in some other kicks. Our subjects generally showed knee angles which were quite flexed at ball contact (45 degrees or greater) compared to previous descriptions (Baker & Ball, 1993, Elliott, Bloomfield & Davies, 1980). It has been suggested that the time of ball contact in the swing is related to the intended height of kicks (McDavid, 1985). Because our subjects were kicking in an indoor laboratory, they may have deliberated tried to kick with a low trajectory. This would mean ball contact would have occurred earlier in the forward swing (with the knee more flexed) and the hamstrings would not be required to contract as much eccentrically to decelerate the leg in the follow through. Further study could confirm whether the EMG pattern is different for the different types and trajectories of kicks made during a game.

The adductor and ilio-psoas muscles were not studied due to a limitation of EMG channels. From our pilot trials, the adductor muscles appeared to have a similar profile to the hamstrings, possibly including some cross-talk. The adductors of the kicking leg would presumably show increased activity in around-the-corner kicks. The gluteal muscles also showed a similar activity profile to the hamstrings, although the gluteals of the stance leg contracted around the time of heel contact, presumably to abduct the stance hip and prevent dropping of the pelvis to the opposite side. The ilio-psoas muscles of the kicking leg would presumably be active in the backswing and wind-up to flex the hip.

In terms of injury mechanisms some observations and comments can be made. The hip joint of the kicking leg moves through a large range over a short time. As the hip joint of the stance leg is relatively stationary large joint reaction forces would be applied through the pelvis, in particular the pubic symphysis. This may explain why osteitis pubis is commonly seen in Australian football (Fricker, Taunton and Ammann, 1991). The individual differences observed in hamstring activation during the follow through phase may represent a difference in hamstring function which may correlate with injury, however it might simply demonstrate the different muscular effort involved in each kick.

The injury in Australian football that most commonly has the mechanism of kicking is the quadriceps strain (Orchard, Wood, Seward & Broad, 1998). It is likely that during a kick, the quadriceps muscle tears at the time of ball contact, when the ball transmits a retarding torque on the extending thigh. If this is the case, the muscle (rectus femoris) strain occurs during a concentric movement when the muscle is inactive (during the follow through phase) – not during an eccentric contraction. There is potential for this torque to be lowered, and hence the rate of injury to be reduced, by changing the mechanics of the ball (such as lowering the pressure of inflation, which may increase contact time and decrease peak retarding torque).

In conclusion, drop punt kicking in Australian football has similarities with soccer kicking and other 'throwlike' motion patterns. The quadriceps (particularly of the kicking leg) and hamstring muscle groups are both highly active and exhibit both concentric and eccentric contractions during the various phases of kicking.

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## TABLES & FIGURES

Table 1: Location of markers

Marker	Name	Location
1	Forehead	Front of headband worn
2	Rearhead	Rear of headband worn
3	Acromion	Acromion of near side
4	PSIS	Posterior Superior Iliac Spine of near side
5	ASIS	Anterior Superior Iliac Spine of near side
6	Greater trochanter	Greater trochanter of near leg
7	Mid thigh	Middle of vastus lateralis, near leg
8	Femoral condyle	Lateral femoral condyle, near leg
9	Head of fibula	Head of fibula, near leg
10	Lateral malleolus	Lateral malleolus, near leg
11	Calcaneous	Most posterior aspect of heel of shoe, near leg
12	5 <sup>th</sup> metatarsal	Lateral aspect of shoe, over base of 5 <sup>th</sup> metatarsal, near leg
13	Ball large	Middle of one half of football
14	Ball small	Middle of other half of football
15	Thigh	Middle of vastus medialis, far leg
16	Knee	Medial joint line of knee, far leg
17	Ankle	Medial malleolus, far leg

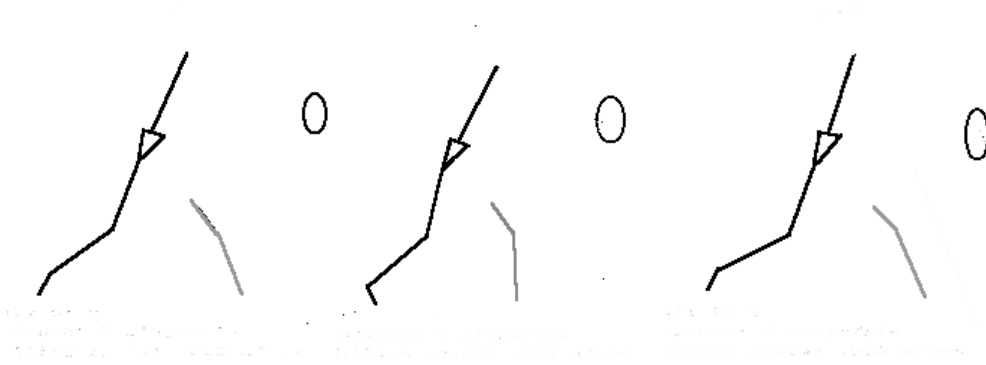


Figure 1(a) End of approach; 1(b) R foot toe-off; 1(c) R hip maximum extension

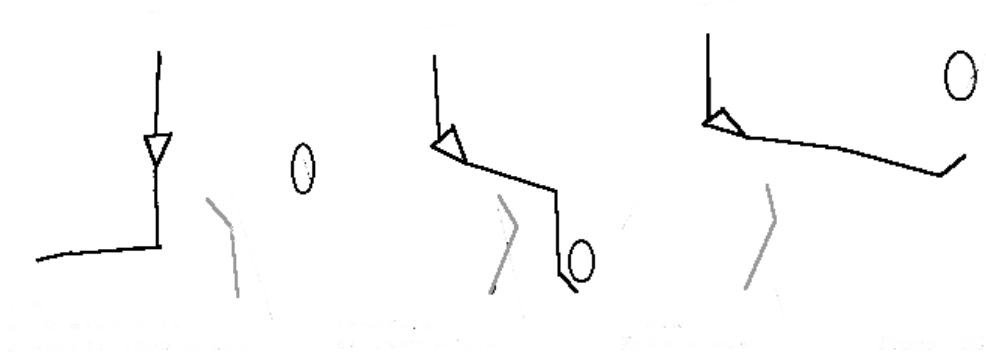


Figure 1(d) R knee maximum flexion; 1(e) Ball contact; 1(f) R knee maximum extension

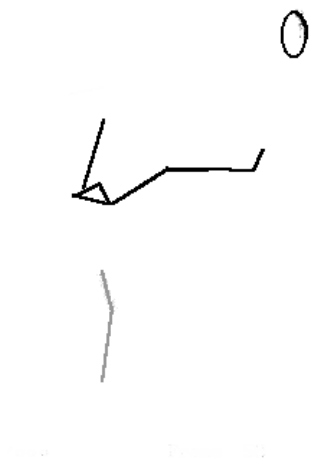


Figure 1(g) R hip maximum flexion



Figure 2 EMG of R foot kick

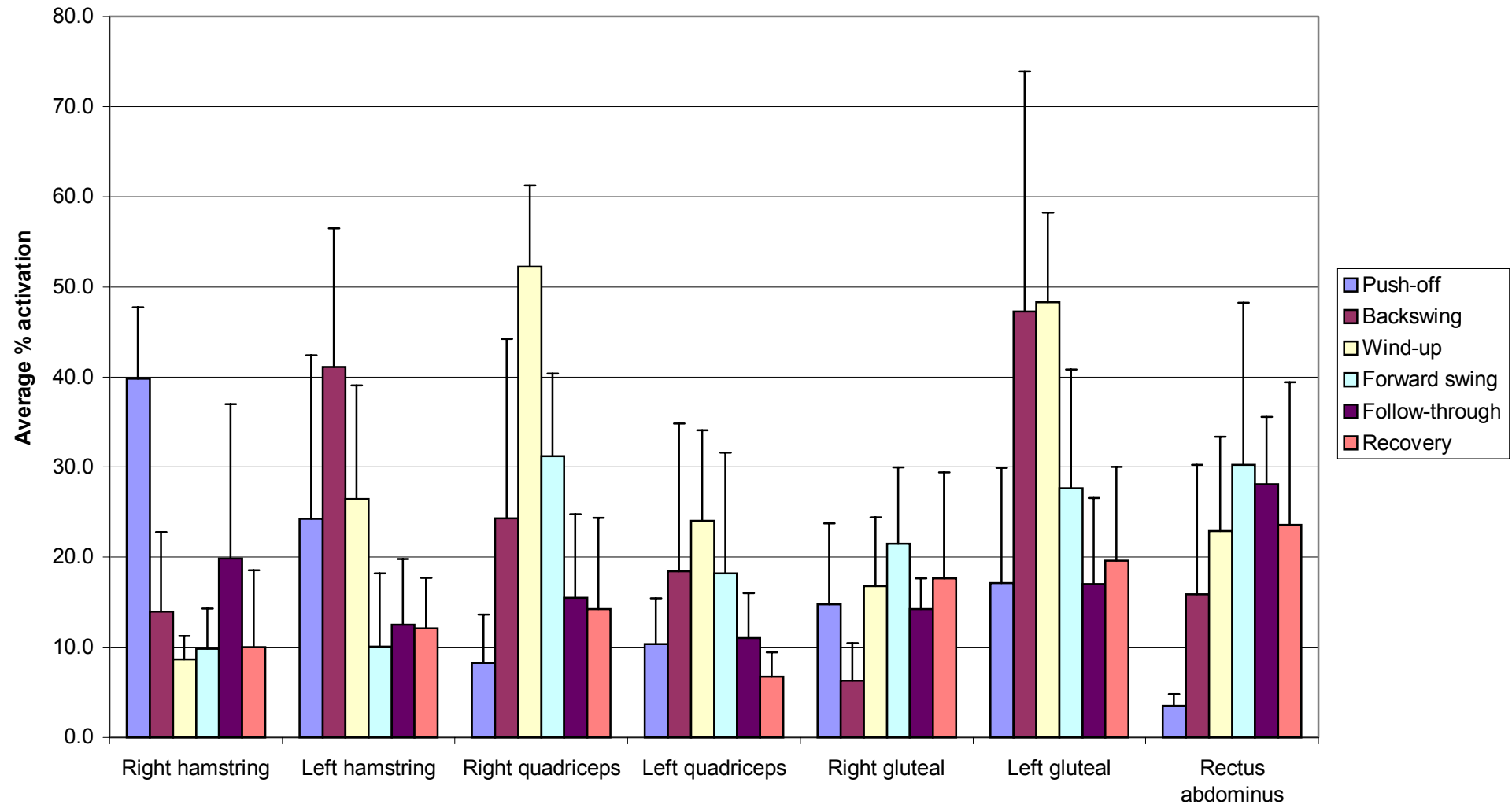


Figure 3 EMG of L foot kick

