B7-1 ID145

THE EFFECTS OF CLEAT LOCATION ON MUSCLE RECRUITMENT STRATEGIES OF CYCLING

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Foot placement may play an important role in muscle recruitment patterns and affect cycling performance. The purpose of this study was to determine if magnitude of activation increased in more proximal muscles when a more posterior compared to standard cleat location is used. Surface electromyography (8 muscles) and kinematics were collected from 11 experienced cyclists pedalling at 80 rpm rate during standard and posterior cleat location conditions. Root mean square (RMS) EMG were analyzed using paired t-tests. Peak RMS magnitude and crank angle of peak RMS were affected by cleat conditions. Posterior cleat locations alter the magnitude and muscular recruitment strategies of seated cycling when compared to neutral cleat placement.

KEY WORDS: Angular kinematics, surface EMG, muscle activation patterns, clipless pedals

INTRODUCTION: Integrated pedal systems, or clipless pedals, are designed to enhance the performance of amateur and professional cyclists. Despite minor variations among manufacturers, the threading to accept cleat hardware is consistently located underneath the third metatarsophalangeal joint (MPJ) region. However, whether this location is the most optimal location for performance is not well investigated and is controversial (Van Sickle & Hull, 2007). Moreover, current cleat standard may promote a higher likelihood for injury (Pruitt & Matheny, 2006; Van Sickle & Hull, 2007). Therefore, determination of an optimal cleat location could potentially reduce injury and promote greater pedalling effectiveness.

Therefore, the purpose of this study was to determine if a more posterior (POS) compared to the standard, neutral (NTL) cleat location would change the EMG activation patterns of lower limb muscles during stationary cycling. We predicted that: a) the POS compared to the NTL cleat location would decrease the magnitude of activation of the triceps surae and increase activation of the quadriceps, hamstring, and gluteal muscle groups; and b) activation of the triceps surae and thigh muscles were anticipated to occur later in the pedal stroke.

METHODS: Our study was a crossover design with cleat position as the independent variable. Eleven healthy experienced male cyclists were recruited from our collegiate team and the local cycling community (age: 28 ± 7 yrs; mass: 73 ± 11 kg; height: 175 ± 6 cm). All participants were familiar with clipless pedal systems and cycled a minimum of 8 hr/mo. All participants provided informed consent.

For the NTL cleat location, the cleat was placed at half of the antero-posterior difference between the first and fifth MPJ. The cleat for the posterior POS cleat condition was located half the distance between the NTL position and the posterior edge of the calcaneus (Van Sickle & Hull, 2007). To accommodate the POS cleat location, research-specific shoes (2010 Specialized Comp™, Specialized Bicycle Components, Morgan Hill, CA) were modified by drilling holes in locations necessary to obtain proper cleat placement, based on anatomical landmarks of each foot.

At the first of two sessions, anatomical features of each foot were recorded to properly position the cleats. To maintain similar cycling positions and motions between cleat conditions and to reproduce the cyclist's natural body positioning, each participant was positioned with the following measurements for all testing: 30° knee flexion at point of terminal extension; anterior aspect of patella located vertically over the 3rd MPJ with crank in horizontal position; absolute trunk angle 40° from the horizontal; and shoulder joint angle of 90°. Next, a cycle ergometer was adjusted to obtain this body positioning with the participant using his own footwear and cleat configuration. The participant then warmed up at a self-selected pedal rate for 5 min. at 100 W. The participant then underwent a cycling ($\dot{V}O_{2max}$) test to determine the maximum workload for subsequent testing. Power was increased by 1 W every 2 seconds was used to elicit a voluntary maximal effort while gas exchange was recorded at 15 s intervals.

EMG and kinematics were obtained at the 2nd test session, 3-8 day later. On the right leg, surface bi-polar Ag-AgCl electrodes (10 mm diameter, 2 cm inter-electrode distance) were placed on the soleus (SOL), medial (MGA) and lateral gastrocnemius (LGA), tibialis anterior (TA), biceps femoris (BF), vastus lateralis (VL), vastus medialis oblique (VMO), and the gluteus maximus (GM); the tibial tuberosity was the location for the common ground electrode (Hermens, et al., 2000). EMG signals (sampling rate = 1200; CMRR = 90db min. at 60 Hz) were synchronized with signals of a 7-camera motion capture system. Reflective markers were placed on the lower extremity (Kadaba et al., 1990). A marker also was placed on the lateral aspect of each shoe directly above the cleat location. For each cleat condition, a 10-minute trial was completed at 80 rpm at a workload of 85% $\dot{V}O_{2max}$. Data were obtained for a 10 s trial at minutes 7, 8, 9 and 10. The order of the two cleat positions were counterbalanced among participants.

Vicon Plug-in-Gait™ software was used to generate joint kinematics. Ten complete cycles of each trial were selected for analysis (cycle starts at 0˚ when pedal is at the top). Maximum flexion/extension angles of the hip, knee and ankle joints were generated to verify if angular kinematics were similar between cleat conditions. Raw EMG data were filtered using a 4th-order band-pass Butterworth filter (30 to 200 Hz). Root mean square (RMS) EMG (T = 50 ms) was generated. Threshold values for determining onset/offset were set at 20% of maximal RMS (Hug & Dorel, 2009). Peak RMS-EMG magnitude (RMS_{max}), crank angle at RMS_{max} ($RMS_{max\text{-}ang}$), and RMS-EMG burst onset/offset times as a function of crank angle ($RMS_{on/off}$) were generated. Paired t-tests and 95% confidence intervals (CI) of difference scores (NTL – POS) were used to detect ($p < .05$) and interpret differences, respectively, between cleat conditions.

RESULTS AND DISCUSSION: Among participants, there was a sizeable range for participant experience (4 – 22 yrs) and $\dot{V}O_2$ max: range = 49.5 – 64.3 ml/kg/min (X ± SD: 55.5 ± 5.1 ml/kg/min). Lower leg angles were not statistically different between cleat conditions (Table 1), whereby the differences were ~2˚ except for one angle (8˚), and the CIs of the difference scores crossed zero. Hence, we believe that the body positioning was fairly similar between cleat conditions.

Support for our predictions for RMS_{max} was mixed (Table 2). For the POS compared to NTL condition, as anticipated, RMS_{max} decreased for the triceps surae and increased for GM. However, TA, VMO, VL, and BF displayed no differences. These outcomes, though, are congruent with a previous study (Van Sickle & Hull, 2007). One explanation, not provable in our study, is that there is a shorter moment arm for the resistance force from the pedal during POS compared to NTL. Therefore, the net ankle muscle moment required could be less, hence, activation of triceps surae was decreased (Farina, 2006). It was interesting that only the GM increased its activation to help counter decreased triceps surae activity. One possible explanation is that increased GM activity was sufficient compensation. Another explanation is that other hip and knee extensor muscles whose EMG was not measured increased their activation.

For $RMS_{max\text{-}ang}$, only VL was activated at a different crank angle within the cycle (32.3° later) for the POS compared to NTL condition (Table 2). Moreover, individual variation was displayed for muscle burst patterns. For most participants, LGA and MGA showed a single burst of activation that occured between approximately 45° and 90° of the crank cycle for both conditions. However, some participants displayed a second burst for these muscles between 160° and 200°. For $RMS_{on/off}$, only the MGA displayed later onset time during POS compared to NTL condition (Figure 1). Only one muscle displaying temporal differences was, in part, due to high EMG interparticipant variability (Hug et al., 2008).

Several limitations existed. Participants performed the task on a stationary bicycle that may have produced outcomes different from those obtained for overground, outdoor pedalling. Additionally, crank arm length was the same for every participant and that may have affected muscle recruitment of cyclists who typically use other crank lengths (Hug & Dorel, 2009). Also, even with a short acclimation period, a POS cleat location was novel. Moreover, it is not known how muscle forces were affected by cleat position.

CONCLUSION: Based on the results of this study, POS compared to NTL cleat location reduces the magnitudes of primarily the plantarflexors during stationary cycling. Outcomes from this research provide indications that there is a need to further investigate the physiological and biomechanical effects of cleat location before we know whether a more posterior position will be beneficial for long-term performance enhancement and injury prevention.

Table 1. Means ± SD of maxium flexion and extension angles for neutral (NTL) and posterior (POS) cleat positions. Upper (UB) and lower bounds (LB) of 95% CIs of difference scores and predicted null differences.

Joint	Angles	Cleat Position		95% CIs				
		NTL	POS	LB	UB	LB	UB	*p*
HIP	Max Flex	86.7 ± 9.9	83.0 ± 12.7	-3.2	8.4	(-5.2	5.2)	0.342
	Min Flex	40.8 ± 8.0	38.8 ± 7.9	-2.2	3.9	(-2.7	2.7)	0.544
KNEE	Max Flex	110.6 ± 8.5	102.3 ± 12.4	-0.4	16.7	(-7.7	7.7)	*0.060*
	Min Flex	30.9 ± 5.0	28.9 ± 5.6	-1.9	4.8	(-3.0	3.0)	0.350
ANKLE	Max DF	17.1 ± 6.7	15.6 ± 6.6	-3.8	5.9	(-4.4	4.4)	0.627
	Max PF	-5.5 ± 4.0	-3.4 ± 6.0	-6.1	2.3	(-3.8	3.8)	0.324

Note. For both tables, **Bold:** $p < .05$; *italics*: possible significance for $p = .05$ to .07.

Table 2. Means ± SD of peak EMG-RMS magnitudes and crank angle when peak RMS occurred for neutral (NTL) and posterior (POS) conditions. Upper (UB) and lower bounds (LB) of 95% CIs of difference scores and predicted null differences.

		Peak EMG-RMS (mV)				Crank angle (º)			
			CI of Diff. Score		*p*		CI of Diff. Score		*p*
		Mean ± SD	UB	LB	value	Mean ± SD	UB	LB	value
SOL	NTL	0.095 ± 0.019	0.020	0.109	**0.009**	84.0 ± 9.4	-16.8	61.7	0.231
	POS	0.031 ± 0.006	(-0.043	0.043)		61.4 ± 65.4	(-37.5	37.5)	
LGA	NTL	0.114 ± 0.063	0.019	0.061	**0.002**	105.2 ± 69.6	-37.9	97.5	0.349
	POS	0.074 ± 0.050	(-0.020	0.020)		75.4 ± 63.9	(-64.7	64.7)	
MGA	NTL	0.153 ± 0.083	0.016	0.105	**0.013**	57.8 ± 24.0	-38.9	18.0	0.432
	POS	0.093 ± 0.047	(-0.043	0.043)		68.3 ± 43.7	(-27.2	27.2)	
TA	NTL	0.058 ± 0.034	-0.035	0.000	*0.052*	72.4 ± 123.4	-86.2	142.4	0.596
	POS	0.076 ± 0.030	(-0.017	0.017)		44.3 ± 94.8	(-109.3	109.3)	
VMO	NTL	0.124 ± 0.056	-0.111	0.029	0.221	61.2 ± 61.2	-31.5	19.7	0.619
	POS	0.164 ± 0.153	(-0.067	0.067)		67.1 ± 33.6	(-24.5	24.5)	
VL	NTL	0.123 ± 0.032	-0.045	0.001	*0.063*	31.0 ± 22.6	-60.1	-4.4	**0.027**
	POS	0.145 ± 0.055	(-0.022	0.022)		63.3 ± 41.8	(-26.6	26.6)	
BF	NTL	0.043 ± 0.029	-0.007	0.009	0.817	92.6 ± 38.3	-21.6	42.4	0.487
	POS	0.042 ± 0.029	(-0.008	0.008)		82.3 ± 57.1	(-30.6	30.6)	
GM	NTL	0.059 ± 0.037	-0.010	-0.001	**0.018**	63.6 ± 23.4	-20.4	0.4	*0.059*
	POS	0.064 ± 0.041	(-0.004	0.004)		73.6 ± 24.2	(-10.0	10.0)	

Note. For both tables, **Bold:** $p < .05$; *italics*: possible significance for $p = .05$ to .07.

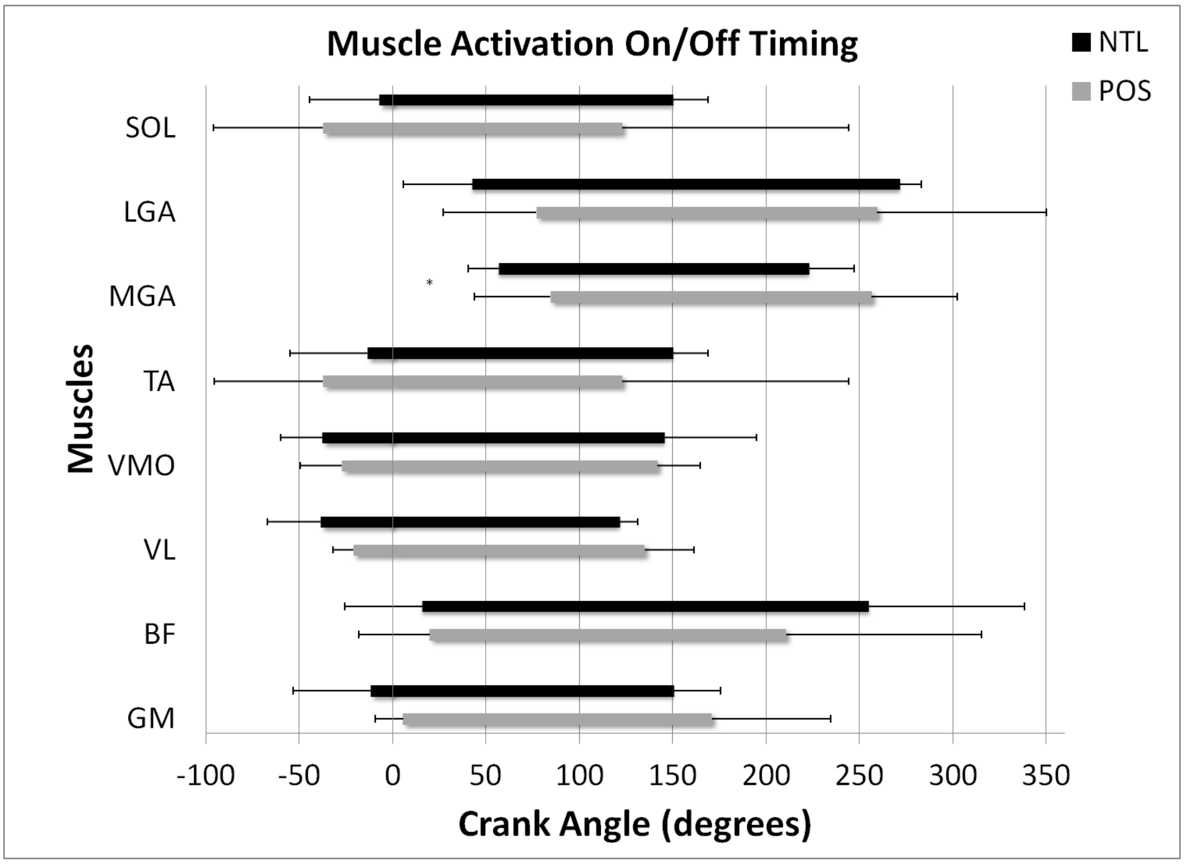

Figure 1. RMS-EMG burst onset/offset times as a function of crank angle for neutral (NTL) and posterior (POS) conditions. Asterisk: *p* <.05.

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Acknowledgement

The authors thank Specialized Bicycles Components for donating shoes to make this project a reality. We also thank Dr. Phillip Tomporowski, University of Georgia, for the use of his lab's metabolic measurement instruments. Thanks also to Dr. Jae Yom, Jayma Lallathin and Rumit Singh for technical assistance.