THE EFFECT OF HIP POSITION/CONFIGURATION ON EMG PATTERNS IN CYCLING

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INTRODUCTION

In human powered vehicles, adjustments in seat-to-pedal distance, pedal crank arm length, seat tube angle, and body orientation (trunk angle with respect to the ground) will result in changes in hip, knee, and/or ankle angles. Changes in these joint angles often affect cycling performance by altering muscle length, muscle moment arm length, muscle angle of pull, force arm length, joint range of motion, and/or the force/torque/power generated by different muscle groups and transferred to the vehicle. The results of previous investigations, examining the effect of changes in hip angles (by a systematic manipulation of seat-tube angles from 0° to 100°) on cycling performance, concluded that there is an optimal hip position/configuration which maximizes aerobic and anaerobic work (Too, 1990a, 1990b, 1991b). However, the mechanism through which these performance differences are attributed is unknown.

Verbal feedback, from subjects participating in those investigations, suggest that muscle fatigue shifts from the quadriceps region at a seat-tube angle (hip position) of 0° to the gluteal region at a hip position of 100°. Muscular fatigue in the position that maximized cycling performance (75° seat tube angle), was reported by subjects to be more generalized throughout the lower extremities; and would suggest a more equitable distribution of load over the various muscle groups. To determine if this is the case, it is necessary to obtain some objective quantifiable form of measurement. It may be speculated that changes in load distribution, on different muscle groups, with changes in hip position would alter muscle activation and recruitment patterns, and reflected by changes in the sequence, intensity, and duration of EMG activity patterns.

Therefore, it was the purpose of this investigation to determine whether cycling performance differences with different hip positions/configurations (angles) are attributed to changes in EMG patterns, as defined by one or more of these: 1) the sequence of activity by the different muscle groups; 2) the duration the different muscles are active; 3) the percentage of a pedal cycle that each muscle is active; and 4) the pedal position each muscle is active and inactive during a complete pedal cycle.

METHODOLOGY

Five male recreational cyclists (age 22-33 yrs) were tested in five different hip position/configuration (0, 25, 50, 75, and 100°), as defined by the angle formed between the bicycle seat tube and a vertical line (perpendicular to the ground) passing through the pedal axis. To accomplish this, a variable position seating apparatus, allowing for manipulations with three degrees of freedom and interfaced with a cycle ergometer, was used. These manipulations included: 1) changes in seat tube angle (hip position); 2) changes in seat backrest angles; and 3) changes in seat to pedal distance. By rotating the seat to maintain a backrest perpendicular to the ground, a systematic decrease in hip angle (configuration) from the 0 to 100° position was induced. For each condition, the seat-to-pedal distance was adjusted to remain 100% (to within 3/4 of an inch or 1.905 cm) of the total leg length as measured from the greater trochanter of the femur of the right leg to the ground.

All subjects were tested in each of the five hip position/configuration according to a randomly determined sequence. Each subject was strapped to the seating apparatus at the trunk and hip with pedal toe-clips worn. In each position, the minimum and maximum hip, knee, and ankle angles were obtained for one complete pedal revolution. A cycle ergometer was used with a resistance of 65 gm/kg of the subject's body mass (3.82 joules/pedal rev/kg BM) and a pedaling frequency of 60 rpm as dictated by a metronome (Too, 1991a).

For each test condition, EMG activity of six muscles of the lower right limb was examined. The muscles were: 1) gluteus maximus; 2) rectus femoris; 3) biceps femoris (long head); 4) vastus medialis; 5) gastrocnemius (lateral head); and 6) tibialis anterior. EMG activity was recorded from surface electrodes placed 3 cm apart over the belly of each muscle. Electrode placement was determined as described by Delagi and Perotto (1981). Prior to electrode placement, the skin at the electrode sites was appropriately prepared. Silver/silver chloride pre-gelled electrodes with a diameter of 4 cm were used in this investigation. The electrode resistance was always less than 10,000 ohms.

A four channel Beckman Dynograph Recorder was used to process the EMG signals. Because six muscles were examined, only three channels were used at one time. After data were acquired in one hip position/configuration, the electrodes were detached and re-applied to the remaining three muscles. In each test condition, data were acquired from the same three channels and their corresponding muscles.

The Beckman recorder and a micro-switch, on-line with a data acquisition system having an A/D converter interfaced to a microcomputer, was used to record EMG activity and pedal position, respectively. A computer program was used to collect the data of each channel at 2000 Hz. A micro-switch mounted on the bicycle ergometer chain guard was used to monitor pedal revolutions and recorded the position of the right crank in the top dead center position.

Prior to data collection in the experimental conditions, baseline EMG activity of the muscles at rest were recorded, as well as during maximal isometric contractions. Maximal isometric contractions were obtained with the use of a Cybex isokinetic dynamometer. In the different hip position/configuration, EMG activity was obtained over a 5 s interval, after the proper resistance was applied, and the subject was pedaling at the prescribed cadence.

For a complete pedal cycle in each hip position, a waveform data analysis program was used to determine: 1) the sequence of activity by the different muscles; 2) the duration of activity; 3) the percentage of a pedal cycle that each muscle was active; and 4) the pedal position each muscle was active and inactive. Repeated measures ANOVA's were used to determine if there were significant differences in EMG activity sequence, duration, and pedal position with changes in hip position/configuration.

RESULTS AND DISCUSSION

Observation of Figure 1 indicate that a systematic change in hip position (with a seat tube angle of 0, 25, 50, 75, and 100°) is accompanied by a decrease in hip angle (to 132.9, 118.2, 99.6, 81.3, and 64°) whereas no corresponding changes were found in knee and ankle angles. This decrement in hip angle apparently causes a change in muscle EMG patterns, as evidenced by a backward shift in the pedal crank arm position of where and when the various muscles were active and inactive during a pedal cycle (Table 1 and Figure 2).

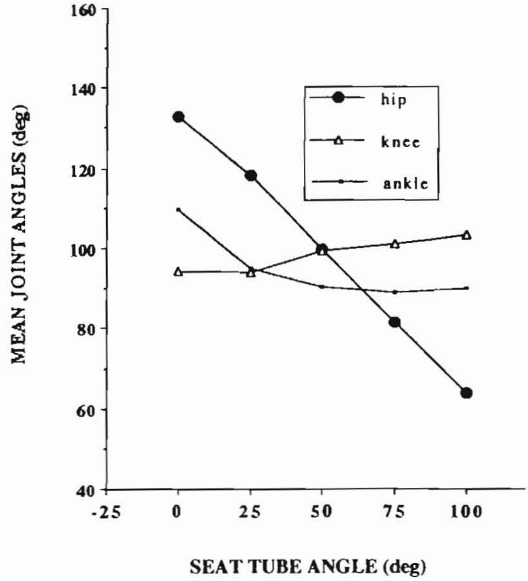

Figure 1. Joint angles with different hip positions (seat tube angles).

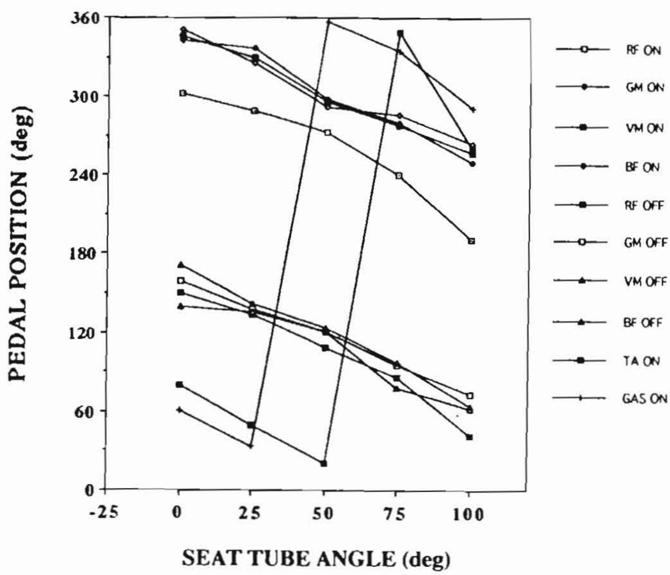

Figure 2. Muscle EMG patterns over one pedal cycle.

Repeated measures ANOVAs revealed significant differences ($p<0.01$) in the pedal position location that the rectus femoris, gluteus maximus, vastus medialis and biceps femoris were active and inactive during a pedal cycle with changes in hip position/configuration. However, no significant differences were found in EMG duration over real time, as a percentage of the pedal cycle, the timing, or the sequence which the various muscles were recruited with changes in hip position/configuration. Post-hoc tests indicate that in almost all cases, the location at which the different muscles were active and inactive in the 0 and 25° seat tube angle were significantly different ($p<0.05$) from that of the 50, 75, and 100° angle. However, depending on the muscle and condition (active or inactive) examined, the 50, 75, and 100° position may or may not be significantly different from each other (Table 2).

Table 1. EMG activity with changes in hip position over one pedal cycle.

Muscles Examined	Hip Position	Duration Active (sec)	Pedal Cycle Active (%)	Location of Pedal Cycle ON (°)	OFF (°)
		Mean (SD)	Mean(SD)	Mean(SD)	Mean(SD)
Rectus Femoris	0	0.56 (0.062)	57.4 (8.19)	302 (45.5)	150 (20.1)
	25	0.55 (0.045)	57.4 (4.37)	289 (8.2)	134 (21.9)
	50	0.51 (0.031)	53.8 (1.69)	273 (8.1)	108 (5.8)
	75	0.55 (0.152)	57.0 (14.9)	241 (45.5)	86 (16.8)
	100	0.57 (0.035)	59.1 (5.93)	190 (34.9)	41 (38.0)
Gluteus Maximus	0	0.47 (0.028)	48.3 (2.54)	343 (8.6)	159 (5.0)
	25	0.44 (0.034)	45.3 (3.72)	337 (19.4)	138 (7.4)
	50	0.48 (0.026)	50.6 (1.80)	298 (13.8)	120 (14.7)
	75	0.47 (0.033)	49.0 (5.00)	280 (14.5)	95 (9.3)
	100	0.50 (0.029)	51.5 (1.55)	249 (10.4)	73 (12.3)
Vastus Medialis	0	0.49 (0.031)	49.1 (0.72)	346 (2.4)	171 (13.8)
	25	0.48 (0.034)	48.1 (2.78)	330 (10.9)	142 (4.4)
	50	0.48 (0.050	50.8 (1.90)	296 (11.9)	123 (26.3)
	75	0.50 (0.027)	50.0 (3.03)	277 (11.1)	97 (6.3)
	100	0.46 (0.037	46.3 (3.12))	256 (16.1)	64 (21.8)
Biceps Femoris	0	0.42 (0.025)	41.5 (3.49)	351 (9.4)	140 (3.1)
	25	0.48 (0.006)	47.7 (1.82)	326 (8.2)	136 (4.5)
	50	0.48 (0.076)	52.2 (2.63)	292 (6.7)	121 (15.6)
	75	0.42 (0.059)	41.9 (5.93)	286 (13.6)	78 (8.6)
	100	0.45 (0.031)	44.0 (2.16)	264 (13.3)	62 (6.8)
Tibialis Anterior	0	0.22 (0.520)	21.0 (2.98)	80 (28.3)	152 (17.2)
	25	0.37 (0.176)	27.3 (4.02)	49 (22.1)	147 (7.9)
	50	0.24 (0.036)	30.0 (7.68)	20 (40.9)	130 (15.6)
	75	0.30 (0.035)	32.7 (0.60)	349 (29.20	107 (26.9)
	100	0.52 (0.160)	48.3 (19.67)	259 (78.2)	73 (8.7)
Gastrocnemius	0	0.26 (0.069)	27.8 (4.57)	61 (23.7)	161 (5.0)
	25	0.36 (0.058)	36.6 (5.30)	33 (23.0)	165 (18.4)
	50	0.42 (0.054)	46.4 (5.58)	357 (15.1)	166 (22.9)
	75	0.48 (0.127)	49.9 (15.1)	335 (13.1)	155 (48.4)
	100	0.56 (0.097)	58.8 (7.83)	291 (14.4)	143 (18.5)

These results would suggest that differences in aerobic and anaerobic cycling performances with changes in hip position/configuration, as reported by Too (1990, 1991) can be attributed to (and observed) by changes in EMG activity. It would also appear that verbal feedback provided by subjects regarding the different hip position/configuration test conditions can be quantified by recorded changes in muscle activity patterns. However, why cycling performance (aerobic and anaerobic) should be affected by a shift in EMG location of where and when a muscle is active or inactive during a pedal cycle, is unknown (since there is no change in timing, sequence or duration EMG activity). It may be speculated that, with a given hip position/configuration, the occurrence of EMG activity at certain locations in a pedal cycle coincide with joint angles and/or muscle lengths that result in greater force/torque production. This may be

attributed to more effective interactions between the muscle length and muscle moment arm length with changes in joint angle over some portion of the pedal cycle with a particular hip position/configuration. Differences in cycling performances may also be attributed to quantitative changes in EMG activity such as: 1) integrated EMG values; 2) percentage of maximal isometric contraction; and 3) peak to peak values with changes in hip position/configuration.

Table 2. Fisher PLSD multiple comparison tests.

	Seat-Tube Angles (°)				
	0	25	50	75	100
0	-	&	# $ & *	@ # $ & + *	@ # $ & + *
25		-	$ & *	@ # $ & + *	@ # $ & + *
50			-	$ & +	@ # $ & +
75				-	@ # $ &
100					-

$p<0.05$

@ - rectus femoris (active)
# - rectus femoris (inactive)
$ - gluteus maximus (active/inactive)
& - vastus medialis (active/inactive)
* - biceps femoris (active)
+ - biceps femoris (inactive)

Because of the uniqueness of the cycling positions and hip configurations used in this investigation, it is very difficult to compare EMG results with those reported in the literature. However, the muscle activity patterns in cycling, discussed by Faria and Cavanagh (1978), most closely resemble the activity pattern in the 25° seat tube angle. This would not be surprising since the 25° seat tube angle hip position is most similar to that of a standard upright bicycle. In addition, the EMG patterns of the 75° seat tube angle in this investigation do resemble those reported by Too (1991a) for the same condition.

CONCLUSIONS

Based on the results of this investigation, it was concluded that: 1) with a systematic change in hip position from 0 to 100° (corresponding to a systematic decrease in mean hip angle from 133 to 64°), there is a backward shift in pedal position location that the muscles were active and inactive; 2) there are no significant differences in muscle activity sequence/timing or duration of activity with changes in hip position/configuration; and 3) differences in cycling performance with changes in hip position/configuration are reflected and can be explained by differences in EMG patterns.

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