THE EFFECT OF BODY ORIENTATION ON EMG PATTERNS IN CYCLING

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In human powered vehicles, manipulation of body orientation often results in changes in cycling performance. These changes in performance may be attributed to alterations in: (1) the aerodynamic properties of the cyclist and vehicle; (2) contribution of the lower limb weight to pedal force production; and/or (3) body configuration (joint angle changes affecting the interactions between the muscle length and moment arm length of the muscle groups involved in cycling). In a previous investigation examining cycling performance in a semi-prone, upright, and semi-recumbent position (the trunk relative to the ground at an angle of 60, 90, and 120 degrees, respectively), it had been concluded that an optimal cycling body orientation exists which maximizes power production (Too. 1991). Because the body configuration (hip, knee, and ankle angle) had been controlled for in that investigation, it had been speculated that differences in power production were attributed to changes in lower limb weight contribution to the total force on the pedals. It is believed that these differences would be reflected by changes in the muscle activity patterns. Therefore, it was the purpose of this investigation to determine whether cycling performance differences with different body orientations are attributed to changes in EMG patterns, as determined by one or more of these: (1) the sequence of activity by the different muscles; (2) the duration of the muscle activity; and (3) the pedal position each muscle was active and inactive during a complete pedal cycle.

METHODOLOGY

Seventeen male recreational cyclists (age 20-36 yrs) were tested in three different body orientation (60.90, 120 degrees), as defined by the angle of the cyclist's trunk relative to the ground (Figure 1). To accomplish this. a variable position seating apparatus was constructed and interfaced with a cycle ergometer, allowing for manipulations with 3 degrees of freedom. This included (1) changes in seat tube angle; (2) changes in seat backrest angles; and (3) changes in seat to pedal distance. A reference cycling position (90 degree orientation) was defined. This consisted of (I) a 75 degree angle formed by the seat tube and a vertical line (Hull & Gonzalez. 1990; Too, 1990. in press); (2) a backrest perpendicular to the ground; and (3) a seat-to-pedal distance of approximately 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. To obtain the 60 and 120 degree body orientation, the entire cycling apparatus was rotated 30 degrees forward and backward from the 90 degree orientation. respectively (see Figure 1).

60 degrees

90 degrees

120 degrees

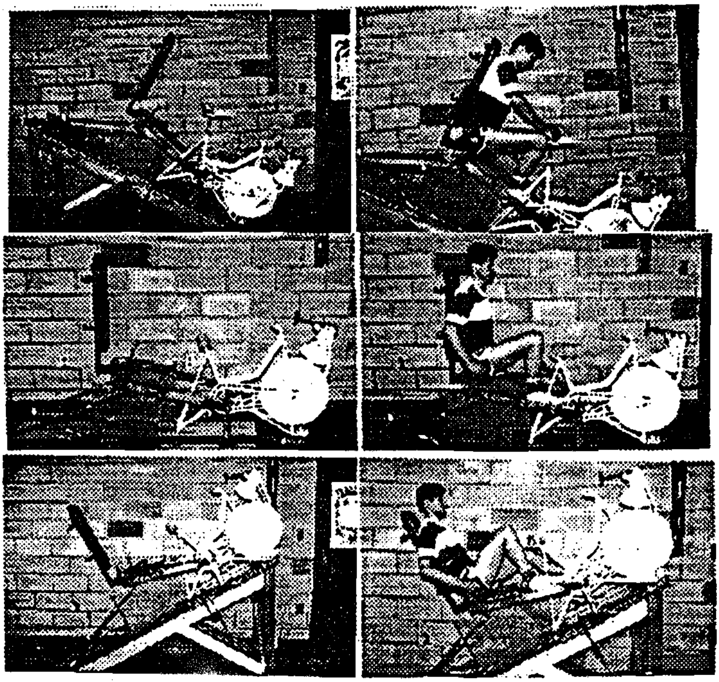


Figure 1. Body Orientations

All subjects were tested in each of the three body orientations according to a randomly determined sequence. Each subject was strapped to the seating apparatus at the trunk and hip with pedal toe-clips worn. The minimum and maximum hip, knee, and ankle angles were recorded at the 90 degree orientation for one complete pedal revolution and then controlled for in the other orientations (with adjustments made in the seat-to-pedal distance). A Monark 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 pedalling frequency of 60 rpm (as dictated by a metronome). There was a minimum of 5 minutes rest between lest conditions, and the ergometer was re-calibrated each time during this period.

For each body orientation condition, EMG activity of six muscles of the lower right limb was examined. The muscles were the (1) gastrocnemius (lateral head); (2) biceps femoris (long head); (3) gluteus maximus; (4) tibialis anterior; (5) vastus medialis; and (6) rectus femoris. 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). Electrode grounds were placed at the tibial condyles and iliac crest. Prior to electrode placement, the skin at the appropriate sites was shaven, abraded with emery cloth to remove the dead skin layer, and cleaned with alcohol. Silver/silver chloride pregelled self-adhering disposable electrodes with a diameter of 4 cm were used in this investigation. The electrode resistance was always less than 10,000 ohms as determined by a Simpson 260 series 8 volt-ohm-milliammeter. The electrode wires were taped to the skin with surgical tape to minimize wire movement and to prevent accidental electrode removal. An elastic wrap placed around the thigh and leg was used to secure the electrode cables and leads.

A four channel Beckman Dynograph Recorder (model R511A) 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 body orientation, the electrodes were detached and re-applied to the remaining three muscles. In each body orientation, data were acquired from the same three channels and their corresponding muscles.

The Beckman recorder and a micro-switch, on-line with a Macpacq data acquisition system having an analog-to-digital converter interfaced to a Macintosh SE microcomputer, was used to record EMG activity and pedal position, respectively. A computer program, Pacqmanager, was used to collect the data of each channel at 200 samples/second. A micro-switch mounted on the bicycle ergometer chain guard was used to monitor pedal revolutions and record the position of the right crank when the pedal crossed the top of it's revolution in the reference cycling position (90 degree orientation).

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 dynanometer. In the different body orientations, EMG activity was obtained over a 10 second interval, after the proper resistance was applied, and the subject was pedalling at the prescribed cadence.

For a complete pedal cycle in each body orientation, a waveform data analysis program (Acqknowledge) by Biopac Systems Inc, was used to determine: (1) the sequence of activity by the different muscles; (2) the duration of activity; and (3) the pedal position each muscle was active and inactive. Repeated measures ANOVA was used to determine whether there were significant differences in EMG activity sequence, duration, and pedal position with changes in body orientation.

RESULTS AND DISCUSSION

Observations of Figure 2 and 3 would indicate that the sequence of EMG activity patterns is very similar in all three orientations. This would suggest that differences in peak power production when cycling in different orientations, as reported in a previous investigation (Too, 1991), is not attributed to changes in the sequence of activation or timing of the various muscles with changes in body orientation. Comparing across cycling orientation for each muscle, the duration of EMG activity and the position of activity during one pedal cycle also appear to be very similar (see Table 1). Repeated measures ANOVAs confirm these similarities because no significant differences (p > .05) were found in (1) duration of EMG activity in real time or as a percentage of the pedal cycle; (2) position in the pedal cycle that the muscles were active; or (3) position in the pedal cycle that the muscles were inactive with the three different body orientations.

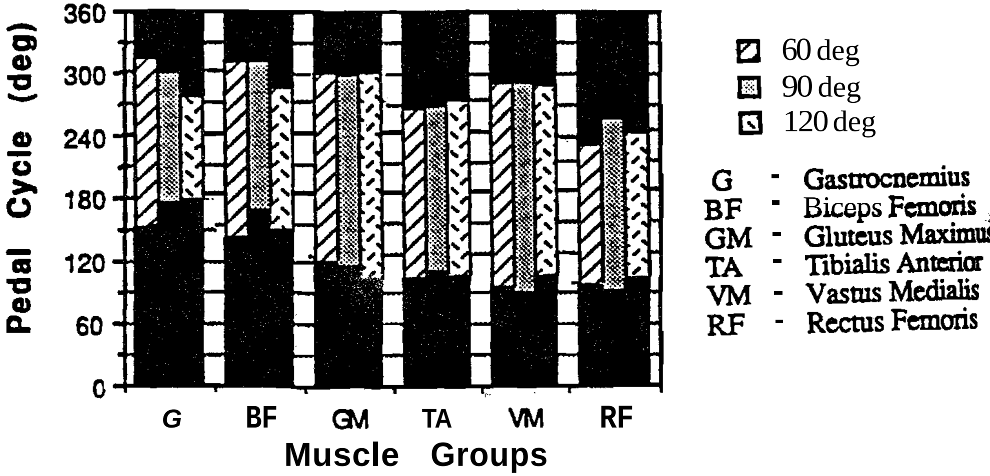
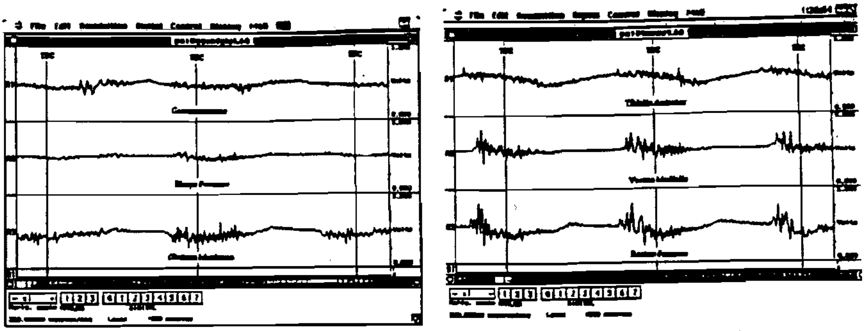


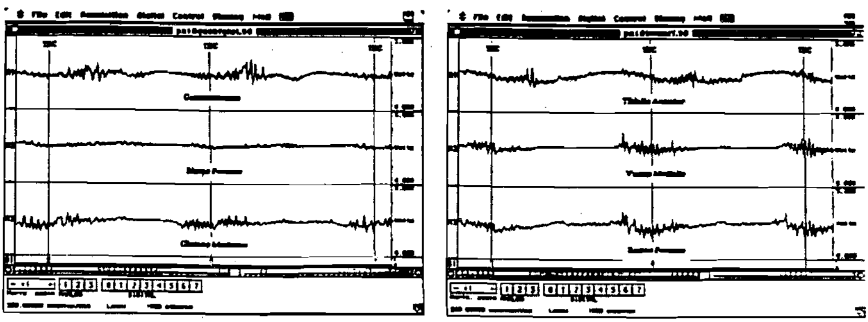
Figure 2. Muscle time diagram.

A sample of the raw EMG signal of the six muscles in the 60, 90, and 120 degree body orientation for subject 10 is displayed in Figure 3. Observations of Figure 3 would suggest that all muscles are active at the top dead center (TDC) position, regardless of cycling orientation. Activity of the vastus medialis at the TDC position is consistent with the results reported by Despires (1974). Faria and Cavanagh (1978). Gregor, Green, and Garhammer (1981). Houtz and Fischer (1959). and Jorge and Hull (1984, 1986). However, activity of the gluteus maximus at the TDC position is only similar to that reported by Faria and Cavanagh (1978). while no activity was reported for the gastrocnemius at the TDC position in the other investigations. For the remaining muscles, activity at the TDC was consistent with that reported in some investigations, but equivocal to those reported in others. These differences may be attributed to varying seat to pedal distances in different investigations and to the body configuration (hip and seat tube angle of 75 degrees) used in this investigation.

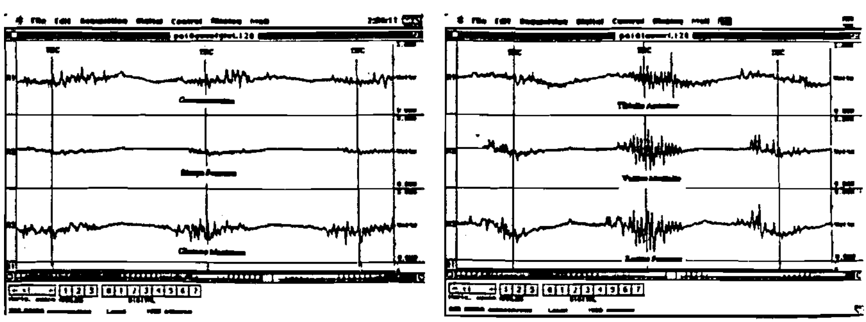
Speculations as to why no significant differences were found may include (1) differences in task specificity and test protocol; and (2) potential differences in quanti-



60 degree body orientation



90 degree body orientation



120 degree body orientation

Figure 3. Sample raw EMG signal of six muscles in the 60, 90, and 120 degree body orientation.

tative EMG values and analyses, as opposed to qualitative ones. The power test described by Too (1991) was the Wingate Anaerobic Cycling Test where a load of 85 gm/kg of the subject's body mass were used (5.0 joules/pedal rev/kg BM) and a 30 second time interval given to accomplish the maximal number of pedal revolution possible. In this investigation, the use of 65 gm/kg of the subject's body mass and the use of a predetermined pedalling frequency may have deviated from the protocol specified by Too (1991) sufficiently to result in non-significant differences between conditions. It is possible that higher loads with unconstrained pedal cadences in a maximal all-out effort may result in significantly different EMG patterns. It is also possible that differences in power production with changing body orientations are not attributed to differences in qualitative EMG patterns. as examined in this investigation, but rather to differences in quantitative ones. These quantitative differences may include differences in: (1) integrated EMG values; (2) percentage of maximal isometric contraction; and (3) peak to peak values with various body orientations.

Table 1. EMG Activity with Changes in Body Orientation over one Pedal Cycle

Muscles Examined	Body Orientation (deg)	Duration Active (sec) Mean (SD)	Pedal Cycle Active (%) Mean(SD)	Location of Pedal Cycle ON (deg) Mean(SD)	OFF (deg) Mean(SD)
	60	0.64 (0.17)	55.5 (153)	314 (25.7)	154 (57.1)
Gastrocnemius	90	0.74 (0.18)	63.9 (13.9)	300 (38.4)	175 (523)
	120	0.69 (0.17)	60.4 (15.1)	277 (98.7)	180 (54.9)
	60	0.62 (0.18)	53.8 (15.9)	308 (18.1)	141 (595)
Biceps Femoris	90	0.73 (0.22)	63.1 (18.4)	310 (18.8)	171 (70.1)
	120	0.64 (0.21)	58.0 (21.2)	283 (78.0)	147 (57.4)
	60	0.58 (0.08)	50.7 (6.7)	298 (15.0)	121 (29.0)
Gluteus Maximus	90	057 (0.14)	50.1 (11.7)	294 (18.6)	116 (495)
	120	051 (0.08)	45.3 (7.8)	298 (15.1)	102 (28.7)
	60	0.64 (0.16)	56.6 (14.8)	262 (46.6)	105 (25.4)
Tibialis Anterior	90	0.58 (0.16)	50.7 (15.0)	266 (71.3)	110 (39.1)
	120	0.63 (0.14)	54.8 (13.4)	270 (375)	108 (30.2)
	60	054 (0.08)	46.9 (5.7)	287 (17.1)	95 (17.6)
Vastus Medialis	90	0.53 (0.12)	46.0 (12.0)	286 (35.5)	90 (12.0)
	120	0.55 (0.09)	48.1 (8.1)	283 (32.6)	108 (41.7)
	60	0.73 (0.19)	64.5 (14.2)	226 (45.6)	98 (13.0)
Rectus Femoris	90	0.63 (0.15)	56.1 (15.7)	250 (48.5)	92 (21.1)
	120	0.67 (0.17)	59.4 (16.7)	237 (54.7)	103 (45.4)

CONCLUSIONS

Based on the results of this investigation, it was concluded that differences in anaerobic cycling performance with changes in body orientation were not attributed to differences in qualitative EMG patterns, as defined by the (1) sequence of activity by the different muscles examined; (2) duration of EMG activity in real time; (3) duration of EMG activity as a percentage of the pedal cycle; (4) position in the pedal cycle that the muscles were active; a (5) position in the pedal cycle that the muscles were inactive. To further address this issue requires examination of the EMG data quantitatively.

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