FORWARD SEAT POSITION EFFECTS ON CYCLING KINEMATICS

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The aim of this study was to identify the effects of fore-aft position of the seat on kinematics during a submaixmal cycling session. Each of four recreational athletes (2 road cyclists, 2 triathletes) completed a 20-km simulated course under two different seat positions: tip of seat 5 cm in front and 5 cm behind the crank axis. Trunk and leg kinematics were determined using three-dimensional motion capture system. Bringing the seat position forward resulted in a more extended trunk-hip region (116±5° vs.122±3° of flexion); however, the source of the extension varied among individuals arising from the pelvis and the thigh in different participants. The knee joint angle range of motion and pattern were unaffected by the seat position. These results imply that participants used different muscle activation strategies in response to the change in riding position.

KEYWORDS: biomechanics, geometry, triathlon.

INTRODUCTION: Triathlon is a sport that involves three different modes of endurance events (swimming, cycling, and running) performed consecutively. Due to the nature of the sport, athletes are required to train and perform well in all three disciplines to become successful. Effective transitions between disciplines are considered one of the keys for a better performance. Although training specifically targeting the cycle-run transition has been attempted, triathletes often express that cycling impairs their running performances. Their testimonies are confirmed by literature that examines the effects of a prolonged cycle on subsequent running. Prior cycling is reported to affect running performance while the effects of swimming on cycling and running performances are considered minimal. An experiment involving a run-cycle-run session reported increased metabolic cost by 2.3 ± 4.6% during a run following a cycling bout compared to a pre-cycling run among non-elite triathletes (Millet et al., 2000). The change in cost demand is thought to be explained by both physiological and biomechanical changes. A pre-run cycling session is shown to change the kinematics (Gottschall & Palmer, 2000) and the muscle activation pattern (Heiden & Burnett, 2003) during running. One of the strategies that have been implemented by triathletes to lessen the effects of cycling on their running performance is changing the bike frame geometry. Specifically, triathletes use steep seat post angles that are more vertical (about 80°) than that of conventional road-racing bikes (between 70 to 76°). Seat post angle affects the seat's relative position to the crank axis. The more vertical seat post in a triathlon-specific bike frame places the rider more directly above the crank axis. This riding position has been shown to improve cycling performance and subsequent run performance (Garside & Doran, 2000) . This position places the cyclist in a more extended lower limb position that appears to influence force production (Ricard et al. 2006) and muscle activation patterns (Brown et al., 1996; Mestdagh, 1998; Ricard et al., 2006) during a pedal cycle. Manipulating trunk tilt alone resulted in changed muscle activation pattern in the leg, and that was likely due to modified joint and segmental kinematics (Savelberg et al., 2003). Despite its effect on performance and muscle activation pattern, the cycling kinematics with forward seat riding position has not been investigated. Therefore, the purpose of this study was to examine the effects of the forward seat position on kinematics during submaximal cycling.

METHOD: Four recreational athletes (3 male – 2 cyclists and 1 triathlete; 1 female triathlete; height: 1.76±0.09 m; mass: 69.4±12.8 kg) who regularly train on either road or triathlon bikes (71.3±35.7 miles/week; 40 mile/week minimum) volunteered and provided written informed consent to participate in the study. Both cyclists and triathletes were included so that the preferred bike geometry types were counterbalanced. In accordance with the study protocol, all subjects participated in at least one event sanctioned by USA Cycling or USA Triathlon during the past 10 months and were free of injury or illness at the time of study. All

procedures were approved by the local institutional ethics review board. The stationary bike set-up was based on five measurements of the participant's bike: seat post length (SPL: distance between the crank axis and the rail of the seat); reach length (RL: horizontal distance between the tip of the seat to the center of the handlebar); seat position (SP: horizontal distance between the tip of the seat and the crank axis); handlebar height (HBH: vertical distance from the tip of the seat to center of the handlebar); crank arm length (CAL), and; number of the teeth on all chain rings.
A stationary bike equipped with an electromagnetic resistance unit (Velotron Elite, RacerMate Inc., Seattle, WA, USA) was set-up to match each participant's personal bike measurements with two variations on the SP horizontal distance from the crank axis of 5 cm in front (road/shallow; ROAD) and 5 cm behind (triathlon/steep; TRI)(Figure 1). The Velotron 3D software allowed the cyclist to ride a virtual course using the virtual gear function that was set to gear ratio options available on the participant's own bike. A clip-less pedal-shoe interface (model X, Speedplay, San Diego, CA, USA) was used to simulate a more realistic riding condition. A pair of aerobars was used to control the riding position. Prior to the actual testing session, each participant rode the stationary bike as long as necessary to become accommodated to the bike. Forty-five retro-reflective markers were placed on the pedals, crank arms, crank axis and the cyclist's body.

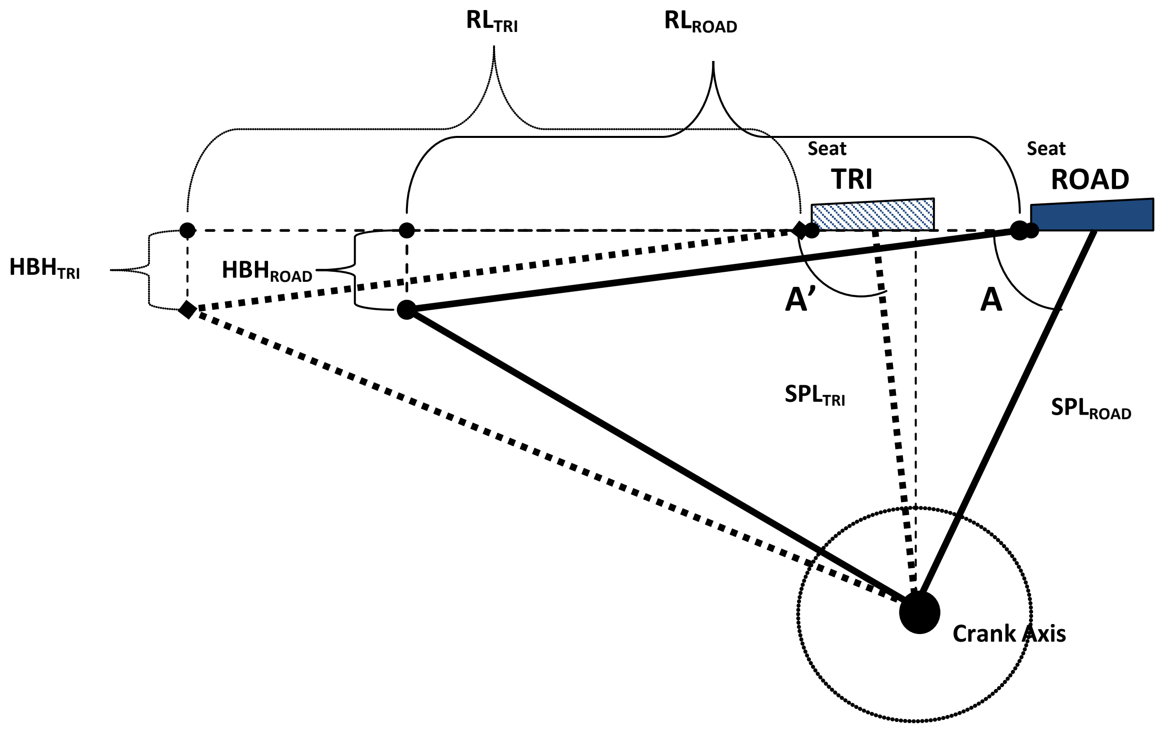

Figure 1. Geometric scheme of the seat position setup for a triathlete bike (TRI; tip of seat 5 cm in front of crank axis) and road bike (ROAD; tip of seat 5 cm behind crank axis). Locations for crank axis, handlebar height (HBH), reach length (RL), seatpost length (SPL) and seat angle (TRI is A'; ROAD is A) are illustrated.

After participants performed their standard warm-up, each rode the ROAD and TRI bike setup conditions in random order at 5-14 days apart. Each participant followed a similar exercise, dietary, and rest routine days into both testing sessions to avoid undesirable effects. The participants rode a 20-km virtual course utilizing the virtual gear to maintain their preferred cadence, with the objective of completing the course in as fast a time as possible. The subject maintained an aerodynamic position with his or her forearms resting on the elbow pads of the aerobars. At 5 km a 30-second data collection of the markers were recorded at 100 Hz using 10 Eagle cameras using Cortex software v1.0 (Motion Analysis

Corp., Santa Rosa, CA, USA). The three-dimensional coordinates of the markers were filtered using a fourth order zero-rag Butterworth filter at cut-off frequencies of 8 Hz (leg markers), 6 Hz (pelvis markers), and 4 Hz (trunk markers). Segmental (relative to a vertical for the trunk and pelvis, and relative to the horizontal for foot/pedal) and sagittal joint (relative to the proximal segment for the trunk, hip, knee and ankle) angles were calculated using Visual3D v4.0 (c-motion, Germantown, MD, USA). All full pedal cycles' for the right limb during the 30-second were interpolated to 360 data points and averaged. Data are presented as means±SD.

RESULTS AND DISCUSSION: Preserving bike set-up measurement while altering horizontal seat position primarily changes the angles at the base of the seat (A and A' in Figure 1 and in Table 1). The angle was larger for the TRI than that for the ROAD bike setup. Increases in this angle are thought to 'open the hip' (i.e. greater extension) to make the muscle length more favorable for the hip musculature (Mestdagh, 1998; Garside & Doran, 2000). The current data support this idea. All of the study participants decreased in relative hip flexion angle with the TRI seat position (Table 1). However, the decreased overall trunk-thigh flexion angle appears to be individualized with different joint angles being altered by the individuals. An experienced triathlete (sub1) accomplished this by decreasing the absolute trunk forward lean, while increasing the anterior tilt of the pelvis. On other hand, one of the participants who was a road cyclist (sub3) extended the trunk-thigh angle while maintaining both anterior pelvic tilt and forward lean of the trunk. Although both of these individuals 'opened up' the hip, one cycled with a greater pelvis-hip angle (sub1) while the other cycled with a lower pelvis-hip angle (sub3) during the TRI condition. Changing the orientation of a single segment (trunk) has shown to affect the muscle length of most of the leg muscles (Savelberg et al., 2003). Therefore, these different strategies used by the participants could possibly suggest different uses of the hip and back musculatures. The commonly accepted definition of the hip angle, the angle between the thigh and the trunk, may not fully describe what might be happening at the hip and pelvis.

Table 1. Seat angle and participant angles (hip, anterior trunk lean, and anterior pelvic tilt) for two bike set-ups (ROAD is tip of seat 5 cm behind crank axis; TRI is tip of seat 5 cm in fron of crank axis) for four participants (sub1 to 4) during a submaximal cycling session.

	Seat angle (°)		Hip angle (°)		Anterior trunk lean (°)		Anterior pelvic tilt (°)	
	ROAD	TRI	ROAD	TRI	ROAD	TRI	ROAD	TRI
Sub1 [T]	79	86	126±18	116±18	77±1	73±1	2±1	16±1
Sub2 [R]	66	68	124±16	123±15	74±1	79±1	25±1	27±1
Sub3 [R]	72	79	119±16	111±18	70±1	70±1	22±1	19±1
Sub4 [T]	68	76	119±16	115±16	71±1	75±1	12±1	22±0

Note: Seat angle is the planar angle at the midpoint between left and right greater trochanters between the crank axis and the handlebar; Hip angle is thigh segment relative to trunk segment; Anterior trunk lean is trunk segment relative to the vertical; Anterior pelvis tilt is relative to the vertical. [T]: triathlete; [R]: road cyclist.

The pattern of the hip joint angle during a pedal cycle was similar between seat conditions. The shift in the magnitude in some individuals appears to be adjusted by re-positioning the pelvis and/or trunk as mentioned above. Knee joint flexion angle was not affected by the seat position conditions in any of the study participants. Both the magnitude and the pattern of the knee angle were preserved with the seat position modification. This finding is consistent with Savelberg et al. (2003). Although no change was observed, this consistency is likely due to the adjustments occurring both proximal and distal to the knee. A few individuals exhibited altered ankle range of motion across the seat conditions. However, each study participant had a consistent pattern in the ankle angle data. There was a tendency of greater anterior tilt of the pedal while riding in the TRI seat position. DeGrood et al. (1994) observed a similar trend among elite cyclists where the pedal was tilted more posteriorly, especially during the downstroke when the seat tube was shallow (67°) compared to when it was steep (80°), although the resultant pedal force did not differ. They suggested that the pedal forces are affected if the intersegmental orientation among the leg, seat tube, crank and the pedal is modified since any changes in intersegmental orientation can affect the length-tension relationship of the working muscles. However, in the current study, as the intersegmental orientation changed (Figure 1) it is possible that pedal forces could be changed as a result of the different seat positions.

CONCLUSION: Changing the fore-aft seat position affected certain segmental and joint kinematics. The more extended position at the hip region was accomplished by vertically aligning the seat with the crank axis; however, the strategy used to obtain the extension appears to vary among the individuals. The changes in kinematics imply that seat position modification likely influences the working length of the leg muscles and the pedal forces. To obtain the comprehensive understanding of the effects of the seat position in cycling mechanics, other measurements, such as pedal forces, joint moments and electromyography should be considered in future investigations.

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