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Sagittal plane kinematics during the transition run in triathletes

Nicole K. Rendos[a,*], Blain C. Harrison[b], Jay M. Dicharry[c], Lindsay D. Sauer[c], Joseph M. Hart[c]

[a] Univeristy of Miami, Sports Medicine & Motion Analysis Laboratory, Coral Gables, FL 33143, United States
[b] Longwood University, College of Education and Human Services, Health, Athletic Training, Recreation, and Kinesiology, Farmville, VA 23909, United States
[c] University of Virginia, Center for Endurance Sport, Physical Medicine & Rehabilitation, Charlottesville, VA 22908, United States

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ABSTRACT

Objectives: Epidemiological evidence indicates more than 70% of all injuries that occur while training for or competing in triathlon happen during running. Maintaining an aerodynamic position on a bicycle during a triathlon places triathletes in a prolonged trunk flexed position which may affect lower extremity running biomechanics following cycling and influence both injury risk and performance in these athletes. The aim of this study was to compare sagittal plane running kinematics after a 30-min cycling protocol to a baseline run without prior exercise.

Design: Descriptive laboratory study.

Methods: Healthy participants with prior triathlon experience ($n = 28$; height = 1.73 ± 0.09 m; mass = 63.0 ± 7.7 kg; age = 24.6 ± 5.8 years) ran at a self-selected speed on a custom-built treadmill surrounded by a 12-camera motion analysis system before and after a 30-min cycling protocol (RPE 12–14). Three-dimensional kinematics were measured before, and at 2-min, 6-min, 10-min, and 14-min post-cycling. A 1 × 5 series of repeated measures univariate ANOVAs were used to determine changes in kinematic parameters resulting from the cycling protocol. Statistical significance was set a priori at ($p < 0.05$).

Results: Peak angles for anterior pelvic tilt ($p < 0.001$), hip flexion ($p < 0.001$), and spine extension ($p < 0.001$) increased and hip extension decreased ($p < 0.001$) at all time points while running following cycling compared to baseline.

Conclusions: Cycling in an aerodynamic position for 30 min induces changes in sagittal plane running kinematics of the spine, pelvis, and hip for at least 14 min following cycling. Alterations in kinematics may increase the risk for lower extremity injuries and affect running performance in triathletes.

1. Introduction

Triathlon is a multisport event combining the disciplines of swimming, cycling, and running into one race. The sport continues to grow in popularity with an estimated 1.2 million Americans completing at least one triathlon event in 2009.[1] With the increase in the popularity of triathlon, there has also been an increase in the number of injuries sustained by triathletes. It is estimated that up to 74.8% of triathletes will sustain an injury while competing in and training for the sport of triathlon.[2] Up to 73% of the injuries sustained during triathlon are associated with the running portion of the multisport event.[3] Previous retrospective questionnaires have revealed that of the proportion of triathletes reporting an injury while triathlon training, 86% had been involved in the sport of triathlon for two years or less.[4] This suggests that less experienced triathletes sustain a higher portion of injuries compared to athletes with more than two years of experience.The transition between the phases of a triathlon (i.e. swimming to cycling and cycling to running) is a unique feature of this sport that can affect injury risk and performance. There is a high correlation between overall triathlon time and run and bike times, but not swim time, making the transition from cycling to running a major determinant in overall performance in the sport of triathlon.[5] The importance of the transition from cycling to running is further evidenced by the fact that up to 70% of triathletes have been seen to run at speeds 10% below their normal 10 km running speed over the first 500–1000 m following cycling in an Olympic triathlon.[6] Triathletes have also reported an awareness of impaired coordination when transitioning from cycling to running, which argues for a competitive advantage favoring those athletes who can minimize this effect.[7–9]

In examining differences in kinematics between participants' standard running patterns and those examined while running following cycling (transition run), a more forward leaning posture, an increase in peak ankle flexion, and changes in hip kinematics are evident in both elite and moderately trained triathletes.[10–12] However, in two of the studies indicated, kinematic changes were evident

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[*] Corresponding author.
E-mail address: n.rendos@umiami.edu (N.K. Rendos).

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in individual subjects, but not different at the group level.[11,12] Altered pelvis and hip kinematics have been implicated in hamstring injuries and low back pain in runners, however, little information exists to explain if cycling can induce similar kinematics during the run segment of a triathlon.[13–17]

In addition to changes in kinematics, changes in muscle activation patterns have also been noted in comparisons between baseline runs and transition runs. Decreases in electromyography (EMG) amplitude of the tibialis anterior and biceps femoris during the stance phase of running have been reported after both a 20 min and 40 km prolonged cycling bout. Additionally, increases of EMG amplitude of the vastus lateralis were noted in the stance and flight phases of a transition run when compared to a control run condition.[9,18] This demonstrates that running kinematics and muscle activity are altered when transitioning from a prolonged cycling bout to running.

A more thorough understanding of the kinematic changes associated with running following cycling may help serve as an initial step for identifying potential risk factors for lower extremity injury and implications for performance in this population. Therefore, the purpose of this study was to compare sagittal plane running kinematics after a 30-min cycling protocol to a baseline run without prior exercise. We hypothesize that sagittal plane peak trunk flexion angle and peak hip flexion angle will increase in a transition run following a 30-min cycling protocol, while both peak knee flexion angle and ankle dorsiflexion angle will remain unchanged. As an exploratory secondary aim, we compared the magnitude of changes in the sagittal plane during the transition run of those individuals with less than two years of triathlon experience to those individuals with two or more years of triathlon experience.

2. Methods

This study was a 1 × 5 repeated measures, time-series design (pretest, posttest) to compare lower extremity and trunk kinematics during running gait after a standardized cycling protocol. The independent variable was time (baseline, 2 min post cycling, 6 min post cycling, 10 min post cycling, and 14 min post cycling) with dependent variables including peak trunk, hip, knee, and ankle flexion angles, peak anterior pelvic tilt, and peak spine and hip extension angles. In order to examine differences related to sport experience of our participants, an exploratory sub-group analysis was performed to identify differences between participants with high (2 or more years) and low (less than 2 years) levels of competition experience.

Recreational athletes with experience in cycling and running and who were participating in running and/or cycling training for a minimum of 30 min, three times per week were recruited for this study. All participants were healthy and active with no history of lower extremity injury within the past six months. Participants were excluded if they had a history of lower extremity or spinal surgery, a history of cardiovascular diseases, pulmonary conditions, or diabetes. Twenty-eight participants (13 male, 16 female, height = 1.73 ± 0.09 m, mass = 63.0 ± 7.7 kg, age = 24.6 ± 5.8 years, triathlon experience = 1.93 ± 1.52 years) were enrolled in this study. Fourteen participants had less than 2 years of triathlon experience (5 male, 9 female, height = 1.74 ± 0.08 m, mass = 62.9 ± 7.8 kg, age = 24.1 ± 4.5 years) and 14 participants had 2 or more years of triathlon experience (7 male, 7 female, height = 1.71 ± 0.1 m, mass = 63.0 ± 7.8 kg, age = 25.1 ± 5.8 years). Experience was determined from the number of consecutive years leading up to enrollment a participant reported they had completed at least one triathlon competition. This study was approved by the Health Sciences Research Institutional Review Board at the University of Virginia, and all volunteers provided informed consent before participating.

Three-dimensional kinematic data during running gait were obtained using a 12 camera VICON MX (Vicon Peak, Lake Forest, CA, USA) motion analysis system operating at 250 Hz. An AMTI multi-axis instrumented treadmill collected three-dimensional ground reaction forces at 1000 Hz (Watertown, MA, USA). The treadmill consists of two side-by-side force platform units (330 mm × 1395 mm) situated behind a larger unit (660 mm × 2750 mm) housed within the center of a 15 m walkway, providing a continuous treadmill surface for both walking and running. Participants ran on the large treadmill for data collection. The mean kinematic parameter curves of the instrumented treadmill have been found to be within one standard deviation (SD) of corresponding overground running curves, indicating that the instrumented treadmill and overground gait are similar, suggesting our results can be applied to an overground run.[19] A Star Trac Spinner Pro® stationary bicycle (Star Trac, Irvine, CA, USA) equipped with a Profile Design Century Aerobar® (Profile Design, LLC, Long Beach, CA, USA) and a clipless spd pedal design, allowing participants to secure their cycling shoes to the pedals, was used for the cycling protocol.

All testing was conducted in the Department of Physical Medicine and Rehabilitation Gait and Motion Analysis Laboratory at the University of Virginia. A marker set consisting of 17 retro-reflective markers was placed over anatomical landmarks on the trunk, pelvis, and lower extremities of each participant. Markers were affixed to the athlete's running shoes over the posterior calcaneous and second metatarsal head. Skin markers were affixed to the lateral malleolus, lateral epicondyle, lateral tibia in a plum line from the lateral epicondyle marker to the lateral malleolus marker, and lateral thigh in a plum line from the greater trochanter to the lateral epicondyle marker on both the right and left sides. Additionally, markers were affixed to C7, T10, xiphoid process, jugular notch, and the middle of the right scapula. A cluster of four markers was securely fastened to the participant's sacrum via PowerFlex® self adherent wrap. A static calibration procedure including four pointing trials was completed to determine the positions of the right and left anterior superior iliac spine relative to the marker cluster.

After a 5-min warm-up walking familiarization period on the treadmill, the participants ran at a self-selected speed for approximately 4 min with 10 gait cycles analyzed during the last minute of the run to provide baseline sagittal plane kinematic data. Participants selected a speed that corresponded with a typical training run speed (7.09 ± 0.82 mph). This self-selected speed was recorded and used as the post-cycling run speed.

After a 5-min rest, participants then positioned themselves in the aerodynamic position on the bicycle and performed a 30-min cycling intervention. Seat height was determined by having each participant perform the cycling protocol with the knee flexed no more than 25° while the leg and crank arm were aligned with the down tube of the bicycle. Seat fore/aft position was determined by having the participant's tibial tuberosity directly over the center of the foot with the knee flexed to 90°. Each participant used their own cycling shoes equipped with spd cleats. Participants cycled at a self-selected velocity and cadence. The 15-point Borg Ratings of Perceived Exertion (RPE) scale was used to minimize the effects of fatigue and discomfort during the cycling protocol.[20] Participants reported his or her RPE to the investigator every 2 min during the cycling protocol to ensure he or she maintained an RPE between 12 and 14.

Immediately following the 30-min cycling protocol, the participants were given 2 min to transition from the bicycle to the treadmill (transition period). Immediately following the transition period, the participants ran at the same self-selected velocity from the baseline run for a total of 15 min in an effort to estimate