

# Design of an Improved Triathlon Bicycle

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**Abstract -- In this paper we present a state of the art, biomechanically efficient triathlon bicycle. The design consists of a short wheelbase, high racing recumbent frame with an elliptical shaped chainwheel and self-adjusting crank arm. The design was simulated and results showed greater ground force generation and speed from the same muscle input as well as reduction of the notorious dead spot**

**Index Terms -- Recumbent frame, elliptical chainwheel, self-adjusting crank arm.**

## I. INTRODUCTION

FOR prolonged success in the competitive world of triathlons, there needs to exist a cooperative link between the physical and mechanical components. Therefore there existed a need for a biomechanically superior bicycle to maximize the power output for the given muscle input while minimizing the strain placed on predominantly used muscles.

The primary constraints surrounding such a design are: the propulsion must only be derived via the legs, and the bicycle must only operate on two wheels.

The crucial criteria for such an objective are: the design must minimize usage of the primary muscle groups, maximize aerodynamics, minimize both construction and retail cost, and maximize the power output generated by the muscle input.

The major assumption made was that the current triathlon rules were flexible and therefore the bicycle dimensioning restrictions were negligible.

Prior to our participation the proposed solutions for creating a state of the art triathlon bicycle focused on the aerodynamics of the handlebars (Aerobars), proper fitting of the rider to the bike, light weight materials and rider positioning in terms of joint angles and comfort [2].

In contrast to the above techniques, our design moved the rider position from upright to recumbent and also improved vital components such as the crank and chain wheel. By "improving rider position, [it] is one of the most effective ways of increasing potential speed" [5] which led us to recline the rider to minimize the frontal area. Secondly, the mechanics of the standard bicycle were analyzed to find areas for improvement. This led us to maximizing the crank torque (adjusting arm) and designing automatic gearing (ellipse sprocket) during the dead spot (vertical crank position).

## II. CONCEPTUAL DESIGN

### A. Overall design

### B. Major components

The major components of our design are a short wheelbase, high racer recumbent frame (SWB High racer), a self-adjusting crank arm which lengthens and shortens at various stages of the pedal cycle, and an ellipse shaped chainwheel which acts like a variable transmission (Up-shifting/downshifting) at key pedal stroke locations.

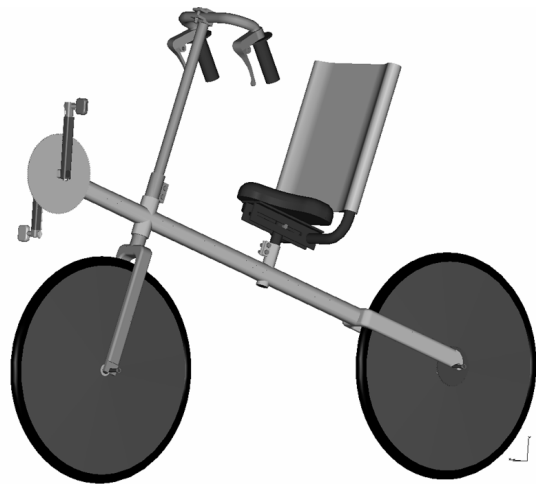


Figure 1: Recumbent design

## III. DETAILED DESIGN

### A. SWB High-racer recumbent

For the most part the SWB high racer recumbent resembles the standard diamond frame bicycle because of their similar wheelbase and similar tire configurations (650c-700c) [1]. For this particular design solid tires have been chosen because they are considered the current state of the art. However, some riders prefer spoked wheels which are perfectly compatible with this design. The rider's position on the bike is in a slightly reclined position. The seat resembles a chair with the front corners cut out of it so it doesn't get in the way of the rider's hamstrings when pedaling. The seat angle is at a 90° angle which is said to be most ergonomic. The handle bars are oriented so the rider's wrists are vertical and about shoulder width apart to provide maximum comfort and ergonomics while keeping the frontal area relatively small.

Therefore, on average, it reduces the frontal area created by the rider and bicycle by 30% which lowers drag [3]. Thus high racers tend to be much faster with the same power input.

On top this they are capable of reaching speeds in excess of 100 km/h as a result of greater force generation by the rider because he/she can resist the pedals with the seat unlike the traditional bicycle [4].

### B. Self-adjusting crank arm

At the top of the cycle the adjusting crank is 18 cm and extends an addition 1 cm as it reaches the horizontal. From here it contracts 1 cm by the 180 degree mark and another by the 270 degree mark before returning to the starting configuration. This is all accomplished by a similar setup to that of a piston/cylinder assembly. There is a sliding cylinder which connects to a stationary portion that is in the location of a standard crank arm via a push rod. The length of the crank arm is controlled by a rotating triangular washer that acts much the same the crank shaft. Below is 3D view of the design.

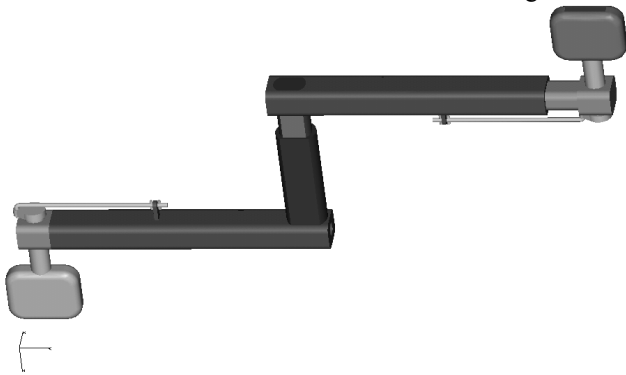


Figure 2: 3D view of self-adjusting crank arm

### C. Elliptical sprocket

Conventional sprockets allow the pedal to follow in a perfect circular path whereas the elliptical sprocket gives the rider a more dynamic boost when either of the pedals is just past the vertical portion of the cycle path, allowing the rider to produce a more efficient pedal stroke.

## IV. DISCUSSION

The implementation of the recumbent frame allows our design to reach greater speeds than the conventional triathlon bicycle with same power input. This stems from the reduced frontal area which helps minimize the effects of drag related forces. The relationship between frontal area and the resultant drag area can be seen in the following,

$$F_D = \frac{1}{2} \rho C_D A v^2 \quad [1]$$

Analysis of equation (1) clearly shows that the drag force shares a linear relationship with the frontal area. On top this it can be seen that the relationship between the velocity and drag force is exponential. Therefore by having lesser frontal area the exponential growth of the velocity is not as evident on the drag.

The adjusting crank arm proved beneficial because of the greater torque that it provides to the pedal cycle when the rider initiates force generation. The greater torque is the result of the extended moment arm at the vital angles of the crank where force application is near or at its maximum. Therefore the

additional gain in torque contributes a greater ground force distribution over a cycle as a result of its transmission through the bicycle drive train.

In addition, the elliptical sprocket provided a benefit much the same as downshifting in a car. The theory behind it is that when the crank is in the horizontal position, rider input is at its maximum and therefore a larger gear can be facilitated. In the case of our design the larger radius of 11 cm represented the standard high gear for a diamond frame triathlon bike. On the other hand when at the vertical stages of the crank pedaling is much less efficient. Therefore the smaller radius is implemented because it is easier to push which allows the momentum of your feet to transition these locations sooner. Thus there is reduction of the dead spot at the vertical position which is the leading cause of inefficiency. The inefficiency exists because the dead spot robs the cycle of a uniform stroke.

Determination of the muscle activity for the recumbent design was made possible by digital photo analysis. A digital camera allowed us to capture nine stages of the crank cycle a rider. With the aid of ImageJ photo analysis software the joint angles (Ankle, Knee and Hip) for the rider were resolved. Figure 3 below shows the determined joint angles.

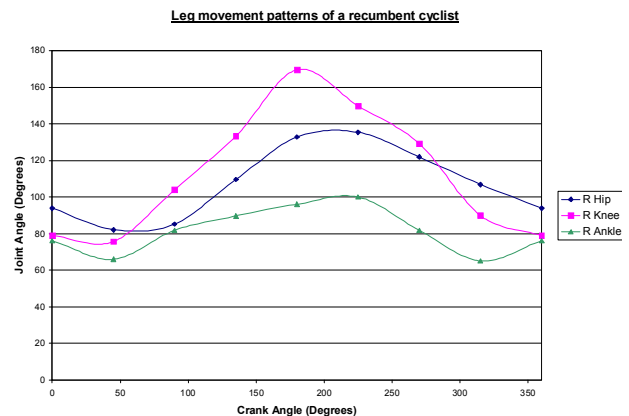


Figure 3: Joint angles of an elite rider

Knowledge of the lower leg positioning allowed for moment balances to be performed about the ankle and knee joints. The determined moments identified the muscles that were active and the degree at which they were performing. The overall analysis revealed a 22% reduction in quadriceps usage and 15% reduction in the hamstring usage. This important finding since participants must run following the bicycle portion.

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