Time Trial Positions in Triathlon, Road and Track Cycling

- Differences and Similarities -

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1 Introduction

This report is part of the course Träningslära II (7.5 Credit Points) within the Trainer program at Gymnastik- och Idrottshögskolan in Stockholm. That report focuses on cycling time trial positions of five athletes from Triathlon (2 athletes), Road Cycling (2 athletes) and Track Cycling (1 athlete).

2 Background

A big range of studies can be found on cycling, especially biomechanics, aerodynamics and training science. Main aspects were to improve muscle activation, innervations and frequentation rate, to develop seating positions referring to functional and aerodynamic subjects, to optimize the transfer of the produced force directly onto the bike and, of course, the energy, physical capacities and power.

Because the disciplines among Triathlon and Cycling, in its sport itself, have great differences referring to distance resp. mainly duration and profile of the course, energy threshold, aerobic/anaerobic load etc., it is hard to find any studies which compare and analyze Time Trial Positions between the best cyclists in their sports and disciplines. There are a lot of analysis of seating positions within each sport, particularly to improve, develop and optimize aerodynamics and biomechanical work for the professional athletes to aim for the best possible performance. So I chose this subject to possibly get an answer to what the main differences are between triathletes and cyclists in their time trial positions and, as well, to compare the cyclists which are among the best athletes in their sport/discipline. The whole analysis is and the technology at the bikes are all based on current status, which means the analysis had been done for actual events in 2010 and 2011. The main task was to determine differences and similarities between sports- respectively discipline-related positions on a Time Trial bike as well as among the best cyclists in these three disciplines. All athletes have won several important competitions, like (Half-)Ironman-Races (Long distance Triathlon) or World Championships, and are all competing at top level in their sports, especially in the cycling part (Triathlon).

2.1 Issues

- Are there distinctive changes for each cyclist in his seating position during the ride?
- Which body parts are mainly subject to distinctive changes?

- What differences and similarities are obvious between every athlete as well as among the cyclists within each discipline and sport?
- What are/could be main influences on discovered differences?

3 Method

Videos for this analysis were downloaded from the internet and converted into a suitable data format to analyze them with cSwing 2008 ©. The Videos contain recordings from actual events in 2010 and 2011. Distances and Competitions can be seen in table 1 on page 8 of this report. All measurements had been made when the athlete was filmed during competition from the left side and in the plane of action (horizontal/vertical). When analyzing with cSwing © six body angles in each of four crank positions during a cycle were recorded. Measurements had been taken for at least four cycles for each athlete. Those values which couldn't be recorded for analysis due to not reliable crank positions were substituted by averaged values from recorded ones and afterwards the diagrams became interpolated for better analysis.

The angles of the Time Trial Positions for each athlete focus on elbow, shoulder, trunk, hip, knee and foot angles in four Crank Positions, which complete one full cycle, independent of the absolute time for such one. Crank Position 1 means the pedal and crank are at the top, which here is stated as 0° respectively the start of a cycle. Crank Position 2 means the pedal and crank position at 90° resp. 25% of a cycle, the pedal was moved into pedaling direction.

The pedal and crank are at the bottom point in Crank Position 3, which also means a movement of 180° and 50% during one cycle. Crank Position 4 states the angles for the pedal and crank position at 270° resp. 75% of a cycle. A full cycle ends if the pedal and crank completed a rotation of 360°, which means both those are back at Crank Position 1 and the next cycle begins.

The angles are all measured along anatomical landmarks. (See Fig. 1). The elbow angle

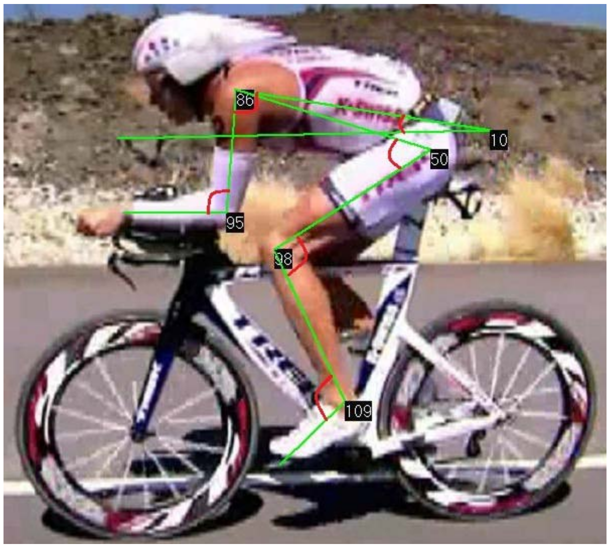

Figure 1 – Measured body angle

is the angle between the longitudinal axes of ulna and humerus. The shoulder angle is measured between the longitudinal axes of the humerus and the trunk. In addition, the trunk angle means the angle between the longitudinal axis of the trunk and the parallel axis of the wheel base, which is the axis from the center of the front hub to the center of the rear hub. This angle has the greatest impact on aerodynamics in cycling. Furthermore, the hip angle means the angle between the axes from shoulder and from knee joint which meet in the hip joint (knee-hip axis: longitudinal axis of femur). The knee angle is measured between the longitudinal axes of femur and tibia and the foot angle between the longitudinal axis of tibia and the axis from lateral malleolus to the distal centre of the metatarsals.

The frame geometry (See Figure 2) has an impact on the position of the cyclist. So it is necessary to take these values into account.

The Head Tube angle is measured between wheel-base axis and longitudinal axis of the head tube. The Seat Tube angle means the angle between the wheel-base axis and the longitudinal axis of the seat tube. Additionally, two Seat Stay angles are measured. Both have their axis center points in the center of the rear hub. The angles lie between the wheel-base axis and the longitudinal axis of the seat stay (bike geometry) resp. the axis from rear hub to the center of the top end of the seat tube (common geometry). The latter seat tube angle is the more important angle in this analysis. The Top Tube angle (slope of the top tube; not in the picture) can be neglected because it is horizontal at the bikes of the five athletes.

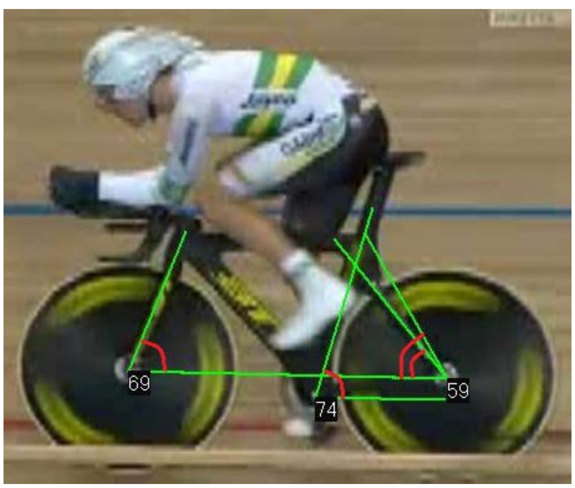

Figure 2 – Frame Geometry

4 Results

Differences stated in this part of the report are referred to the maximum differences of minimum and maximum angle values within each Crank Position.

4.1 Result Description

Chris Lieto has only few changes in his elbow, shoulder and trunk angles during his ride. The differences of minimum and maximum values for these angles lie within 3 and 5 degrees. Only marginal “offbeat” movements appear during his cycling performance. The largest differences are to be found in hip, foot and knee angles (9, 10 resp. 14 degree). In the course of measurement can be seen smaller foot (especially between Crank Position 4 and 1) and knee angles (Crank Positions 2 and 3) but larger hip angles (between Crank Position 4 and 1), which is caused by a slightly uphill ride what will be focused on in the discussion.

Sebastian Kienle shows a very constant performance during his bike ride. Elbow, shoulder, trunk and hip angles differ only between 2 and 4 degree within each crank position. The knee and foot angles have maximum differences of 11 resp. 12 degree. He has the lowest foot angle throughout his ride compared to all athletes.

Jack Bobridge has some varieties in the maximum difference values. Only the trunk angle stays in a constant position almost all the time (maximum difference is 4 degree). All other angle differences fluctuate between 8 and 11 degree. The two unusual peaks at elbow and shoulder angles (around fourth and sixth cycle) are due to backward moving from the tip of the saddle onto the middle part.

The maximum differences for the angles in each crank position for Tony Martin stay between 2 and 8 degree with shoulder and trunk angle differences the lowest and those for elbow, hip, knee and foot the greatest values. The only value which becomes “anomalous” is the low foot angle right in the beginning of the record, which occurred while Tony Martin moved a small distance back on his saddle.

The maximum differences in angle values vary a lot at Fabian Cancellara’s bike ride, ranging from 4 (trunk angle) and 8 (elbow, shoulder, foot angle) up to 14 resp. 19 degree for hip and knee angle. The distinctive great differences in hip and knee angles will be discussed later.

It is obvious that Jack Bobridge and Fabian Cancellara are riding at very high cadences which result accordingly in high angle velocities and faster cycles (see Table 1). Especially the triathletes ride at a lower cadence between 87 and 94. Tony Martin rides at 94 cycles per minute which is the most efficient cadence in both triathlon and cycling to take care of the endurance and power threshold.

If trunk angles are analyzed extremely flat positions can be found for Sebastian Kienle, Fabian Cancellara and Jack Bobridge. This is also stated by the steep Head Tube and Seat Tube Angles for Sebastian Kienle (see Table 2). Tony Martin and Chris Lieto stay at slightly higher trunk levels what may have different reasons.

Table 1 – Competition Duration, Cadence and Angle Velocity of each Athlete

	Chris Lieto	Sebastian Kienle	Jack Bobridge	Tony Martin	Fabian Cancellara
Competition	Ironman Hawaii	Triathlon Buschhütten	Individual Pursuit (Track)	Individual Time Trial	Individual Time Trial
Distance [km]	180	40	4	27	45,8
Time	4h23'17"	58'55"	4'21,141"	33'24"	58'09,19"
Average Pace [km/h]	41,01	40,74	55,14	48,50	47,26
Cadence [cycles/min]	94 (80)	87	118	94	115
Time per Cycle [s]	0,64 (0,75)	0,69	0,51	0,64	0,52
Angle Velocity [°/s]	562,50 (480,00)	521,74	705,88	562,50	692,31

Table 2 – Frame Geometry of each bike

Angles [°]	Chris Lieto	Sebastian Kienle	Jack Bobridge	Tony Martin	Fabian Cancellara
Head Tube	70	75	69	66	68
Seat Tube	76	86	74	79	74
Seat Stay (Common)	56	59	59	62	61
Seat Stay (Bike)	40	54	50	48	49

4.2 Elbow, Shoulder and Trunk Angles

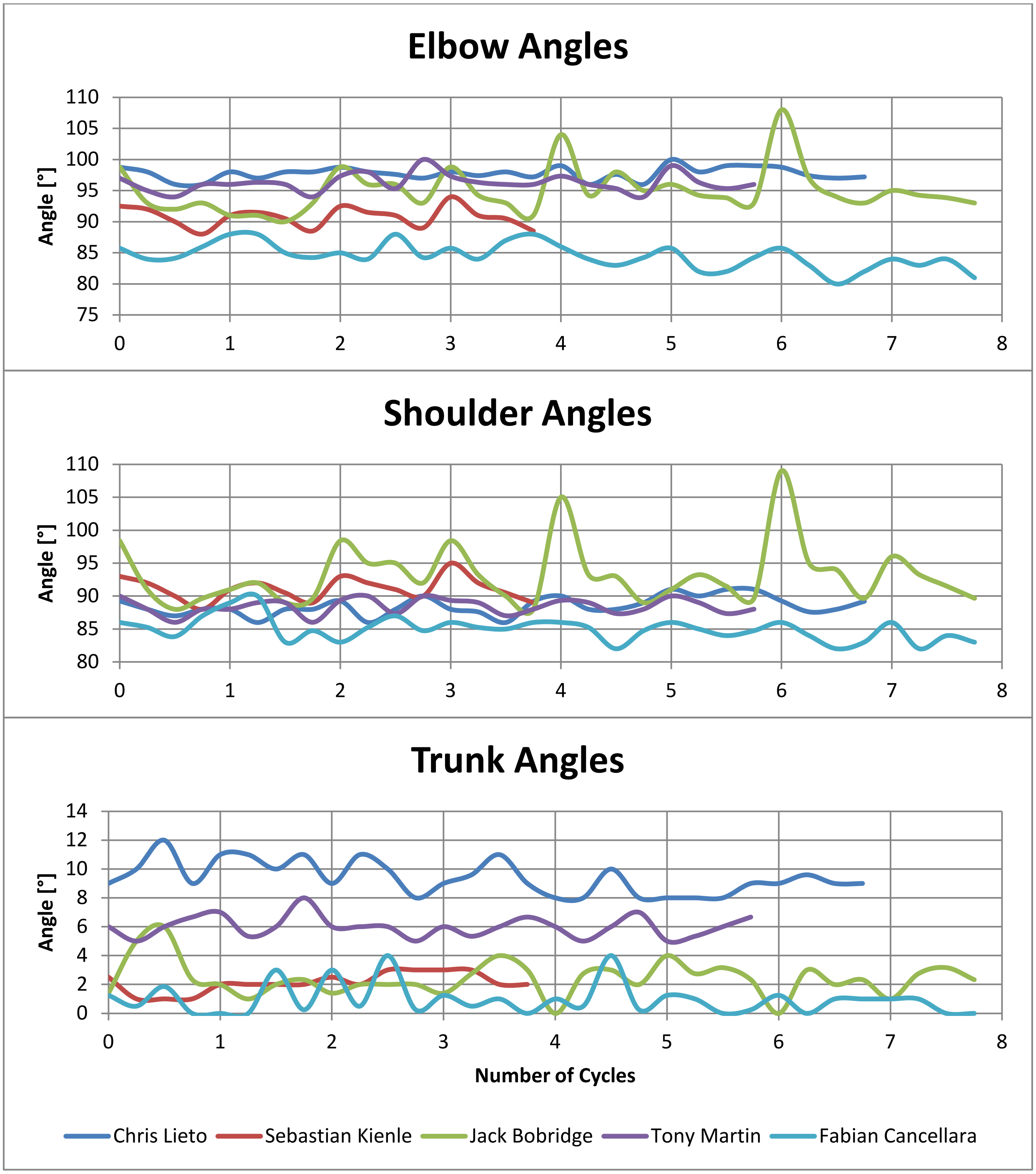

Figure 3 – Elbow, shoulder and trunk angles in Time Trial Positions for each athlete

4.3 Hip, Knee and Foot Angles

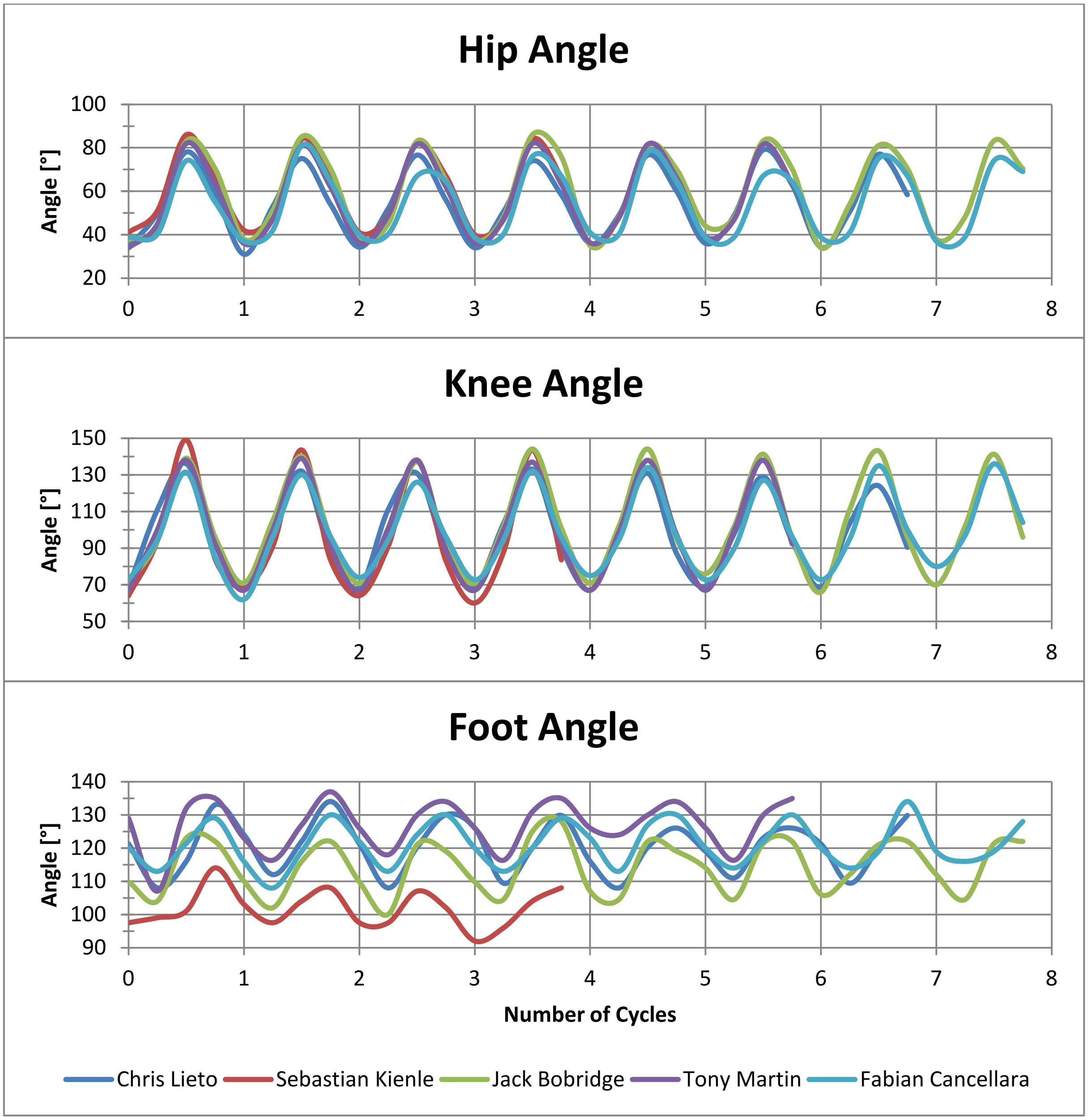

Figure 4 – Hip, knee and foot angles in Time Trial Positions for each athlete

5 Discussion

5.1 Discussion of the results

The marginal "offbeat" movements in elbow, shoulder and trunk angles produced by Chris Lieto are caused by the fact that the movement at such a high repetition rate as in a 180 km bike ride can't be repeated exactly the same over the whole distance. But he limits the movement which is out of the average to an excellent minimum. That means Chris Lieto stays very stable with his arms on his aerobars and with the trunk. These few movements state a good force production from the legs, what is very important to achieve effective power transfers from body to bike. Almost every movement of the upper body parts could result in a lateral movement of the bike. Furthermore, a part of the produced force would not be transferred to bike velocity and it means an inefficient expenditure of energy with every stride. Especially on such long rides as in an Ironman it is essential to be as efficient as possible but to save energy both at the same time.

The two measurements, each one on flat and on slightly hilly part of the bike course, led to technique changes for Chris Lieto. During the ride on the flat part the stride consists of a pressure and a pull phase with an almost balanced ratio. The technique change along the hilly part is expressed by a stronger and extended pressure phase for both legs, which results in the stated smaller foot (especially between Crank Position 4 and 1) and knee angles (Crank Positions 2 and 3) but larger hip angles (between Crank Position 4 and 1) because the thigh descends if the foot (here: the heel) is at a lower position.

The very constant performance during Sebastian Kienle's bike ride means he works mainly with his legs, which is very economic and efficient to produce the most possible power which is transferred directly onto the bike. This force leads to the best velocity he is able to perform. The quite large differences of knee and foot angles are due to his strong power output from his legs onto the bike.

Due to the very short competition duration in a 4000m Track race (Individual Pursuit), which took Jack Bobridge 4:21 Min in the final of the World Championships in Apeldoorn in 2011, it is essential to use every power possible in this short time to achieve the best load and performance. So it came that he had several varieties in the maximum difference angle values for almost all measured angles. But, at the same time, the cyclist has to watch his energy level carefully to avoid exhaustion caused decrease in power. A constant and solid trunk angle like Jack Bobridge realized is important for the aerodynamics, especially at high speeds between 55 and 60 km per hour. The other varying angle differences, like written above, appear due to the enormous load he produces. Jack Bobridge works hard on his bike, trying to produce the best load with pulling at his bar ends which, in that case, function as an abutment to both stay rigid on his bike and also generate power by including more muscle groups which get activated.

Tony Martin stays quite steady in his position on the bike and allows only some few changes during the competition. The movement of sliding back onto the saddle happens, especially when exhaustion appears, so that the cyclist slips to the front tip of the saddle. One reason can be a slight decline of the saddle which causes the cyclist to slip forward. In that position it is more comfortable because the rider isn't extended that hard as before but it is not as efficient as if the cyclist sits in the middle part of his saddle. All settings concerning optimized aerodynamics, velocity, power output and muscle activation were accustomed for the middle position on the saddle. Slight changes may cause a decrease in load and energy during a long ride, which lasts for professional cyclists between 30 Min. and 1:10 hours depending on the distance and the profile.

Fabian Cancellara is able to produce very high loads over long periods on a time trial bike. He reaches an enormous power output because he pushes and pulls the pedal very hard and fast. That is the reason for the very widespread angle values he realized, especially knee and hip. At a cadence of about 115 cycles per minute Fabian Cancellara pulls his leg up as high and efficient as possible but also uses the full pressure phase to work load on the pedal and bike. If Fabian Cancellara's ride is being watched from behind, it is obviously how much movement appears vertically while pulling and pushing with the legs because the hip moves alternately up and down during a cycle. But the most important fact in this case is that he stays stable in the medial part of the hip which means he doesn't lose any energy produced and transfers the power onto his bike.

Fabian Cancellara and Jack Bobridge have high cadences during their rides. In combination with a high amount of work load they achieve optimal high speeds throughout the competition. In 4000m Track races it is usual to have cadences of 115 to 125 cycles per minute but Fabian Cancellara as a road cyclist maintains at high cadences like here of 115 cycles per minute to realize velocities of 47 km/h over a period of almost one hour. In comparison, the other cyclists especially the triathletes stay at lower cadences which are mainly used and are effective to realize constant high velocities.

Extremely flat positions as for Fabian Cancellara, Sebastian Kienle and Jack Bobridge indicate high standovers, which means that the hip is significantly higher than the forearm and elbow. These extreme positions are perfect for aerodynamic conditions because the resistance area of the trunk, which body part has the biggest influence on aerodynamics in cycling, is as small as possible. But it is very hard to ride a long time in such a position. Although, Chris Lieto and Tony Martin haven't got such flat trunk positions, they still manage to achieve flat positions, lying on their aerobars, which allow them to have both minimal resistance area and excellent biomechanical conditions for realizing best possible work and load. A main aspect of the reasons for the diversity of trunk positions even among the best cyclists must be seen in anatomical differences. For instance, flexibility can be limited by bigger muscle cross-sections or disproportional upper and lower body parts may be a limiting factor. Especially in Chris Lieto's case the slightly higher trunk angle settings are more influenced and caused by the duration of the discipline and competition itself. Furthermore, he had to run a marathon immediately afterwards where a bike ride of several hours at high muscle activation level has a great impact on the performance. The reason is that lower positions stiffen mainly the back, hip and hamstring muscles much more what makes it quite impossible to run normally.

The foot angles show that Sebastian Kienle leaves his foot at the lowest angle among all athletes all the time. That means he works a lot with his anterior lower leg muscles during the pulling phase. It is obvious that Tony Martin, Fabian Cancellara and Chris Lieto extend their foot extremely during the pulling phase so that they are working much more with the posterior lower leg muscles and mainly anterior thigh muscles to manage high activity during the pulling phase.

5.2 Conclusion

Summarizing can be said that there are mainly individual differences among all athletes, which have anatomical or biomechanical background. Furthermore, the disciplines establish borders within where the athlete should adjust the settings for his time trial position. The shorter a discipline and therewith the duration of the competitio the more aerodynamically and "extreme" the position can be fitted but within anatomical and biomechanical possibilities. The longer the competition lasts and especially in a triathlon with further disciplines the more a "comfort" factor should be combined with aerodynamic conditions to ensure the best performance on the bike throughout the whole duration and with respect to the running part afterwards.

5.3 Errors

Despite all appropriate measurements it was not possible to lead out very exact values, so that a small margin of error should be taken into account. Main reasons for that are different conditions when filming the athletes, missing values due to lower frame rates at filming and, therewith, the interpolation at more or less insufficient value amount. Anatomical landmarks could not be marked, so that there could be a slight deviation for the angle values as well.

Furthermore, it was a field study what means that the events took place in real conditions and extrinsic disturbances are not excluded.

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