Journal of Science & Cycling
Breakthroughs in Cycling & Triathlon Sciences

OPEN ACCESS

Brief Review

Has 'Aero Is Everything' Gone Too Far?

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Received: 12 December 2023; Accepted: 19 December 2023; Published: 31 December 2023

Abstract: In recent years, there have been a number of high-profile crashes within professional cycling time trials. This has led to concerns over the safety of cycling time trial positions. The main reason athletes are adopting these unsafe positions is to improve their aerodynamics. One of the techniques that athletes are utilizing is to ride with their head-down, which as a consequence severely reduces their visibility. This technique not only compromises the athletes' safety but there is also empirical evidence to suggest that it may not actually lead to improved aerodynamics. This brief review provides recommendations on an evidenced-based approach to dissuade athletes from employing this technique and improve the overall safety of cycling time trial positions.

Keywords: Aerodynamics, road safety, cycling biomechanics, time trial

1. Introduction

Over recent years, the safety of cycling time trial positions has been a topic of considerable debate. This debate has been fuelled by a number of very high-profile crashes, including that of Tour De France winner Egan Bernal in 2022 and four-time winner Chis Froome in 2019. However, perhaps more notable, given the gruesome images circulating of the aftermath, was Stefan Küng's crash at the 2023 European Championships. The crash involved Küng, a highly experienced and decorated cyclist, riding headfirst into the barriers. This resulted in a concussion, broken cheekbone and fractured hand. When asked about the incident, Küng acknowledged that his riding position was a causal factor in the crash. He described riding in a time trial position as being "basically blind… I can only see a few meters ahead" (Becket, 2023).

For context, at 45 km/h a cyclist will travel 12.5 m/s with a stopping distance of approximately 28 m (RideOn, 2013). However, the average speed of professional cyclists, such as Stefan Küng, will often exceed 50 km/h. As the speed of the cyclist increases the distance travelled per second and stopping distance also increase. From these values, it is very clear that having a visibility of only a "few meters" seriously compromises the safety of a rider. This paper will first discuss why cyclists are choosing to adopt unsafe riding positions and the implications of this for bike fitters. It will then consider how bike fitters, governing bodies, and cycling manufacturers can safeguard against this

2. The Rise of Unsafe Riding Positions

Although there are a number of reasons as to why cyclists have begun to adopt increasingly unsafe time trial positions, the primary reason has been to improve their aerodynamics. Over the last few decades, aerodynamics has become an important consideration for many cyclists and long-distance triathletes, both amateur and professional (Giljarhus et al., 2020; Malizia & Blocken, 2020; 2021). This is due to aerodynamic drag being the predominant resistive force whilst cycling (Debraux et al.,

2011). At high speeds (≈50 km/h) aerodynamic drag accounts for approximately 90% of the total resistance acting on the rider (Grappe et al., 1997). Although the bike accounts for some of the aerodynamic drag, the cyclist is the main source of this (Defraeye et al., 2010). The aerodynamic drag of a cyclist varies depending upon the posture/positioning of the rider (Barry et al., 2015; Faulkner & Jobling, 2020; García-López et al., 2008; Giljarhus et al., 2020; Schaffarczyk et al., 2022). Positions that reduce the frontal area of the cyclist and create a more streamlined shape through the air (i.e., reducing form drag) have generally yielded the most successful results in terms of reducing aerodynamic drag (Barry et al., 2015; Grappe et al., 1997). However, some of these positions have been deemed by the Union Cycliste Internationale (UCI), the world governing body for cycling, as unsafe and have subsequently become banned in UCI regulated competitions. Examples include the tucked position developed by Graeme Obree and superman position adopted by Chris Boardman in the 1990's (Malizia & Blocken 2021).

A more recent position/technique that some riders are employing, in an attempt to reduce their frontal area and therefore aerodynamic drag, is to look directly down at the road. In professional cycle racing, the rider then relies on clear directions from his/her team through the race radio to avoid any obstacles and navigate the course. In events (e.g., triathlons) where race radios are prohibited, riders may use the white line on the road as a guide, looking up occasionally to see where they are going. Despite some practitioners advocating that looking down is faster, at present there is no empirical evidence/research to support this assertion. To the contrary, a number of studies have found this to be detrimental to performance (e.g., Barry et al., 2015; Beaumont et al., 2017). Barry et al. (2015) conducted wind tunnel testing to examine how a rider's posture can impact aerodynamic drag. Lowering the eyes and head was found to increase drag both whilst riding in the drops and in a triathlon position. Barry et al. (2015) suggested that this could be due to the geometry of the helmet utilised in the study. Beaumont et al. (2017) used Computational Fluid Dynamics (CFD) to examine the aerodynamic properties of time trial helmets in two different head positions: head-up (i.e., horizontal eye gaze) and head-down (i.e., vertical eye gaze). Regardless of helmet shape the head-down position resulted in greater aerodynamic drag. The findings of the aforementioned studies refute the assumption that riding with a head-down position provides an aerodynamic advantage. However, there are other, perhaps unintentional, reasons as to why riders are adopting this unsafe position.

In terms of determining whether a position is safe and a rider has an acceptable level of visibility, it is also important to assess the position's sustainability (i.e., can the rider maintain this throughout the duration of the race). An aerodynamic position is often achieved by reducing a rider's torso angle, which subsequently lessens the airflow around the body reducing drag (Faulkner & Jobling, 2020). However, maintaining a flat torso requires the athlete to have a good hip flexion range (Wadsworth & Weinrauch, 2019). For a rider with limited hip flexion, weak core muscles, and/or poor upper body strength holding an aerodynamic position whilst maintaining a good line of sight will be challenging. However, it may be possible for a relatively short period of time indoors on a static trainer (i.e., the environment in which a position is generally set). That being said, when the intensity and/or duration of the effort increases the rider's technique and posture may begin to falter. Research has shown that cyclists' joint kinematics change under increased load (Bartaguiz et al., 2023; Holliday et al., 2023). Changes were observed in lower body kinematics (Bartaguiz et al., 2023; Holliday et al., 2023) but also in shoulder and back joint angles with both becoming more flexed during higher intensity efforts (Holliday et al., 2023). These kinematic changes could potentially lead to difficulties in the rider seeing where they are going, compromising their safety.

Another performance-orientated factor which can serve to compromise the safety of a position is the placement and/or extreme preoccupation with a cycling computer and the data it provides. Bayne et al. (2020) examined the impact of single (i.e., elapsed time) versus multiple forms of feedback (i.e., time, speed, elapsed distance, elapsed time, power output, cadence and heart rate) on performance during an indoor 30-minute time trial. Multiple feedback was found to impair performance relative to single feedback. The authors believed this to be due to the mental overload associated with exposure to too much information. When exposed to multiple feedback metrics, cyclists/triathletes spent 15% (i.e., 4 minutes 30 seconds) of the time trial looking at this data. If this finding translates to cyclists/triathletes behavior on the road, this suggests that they may spend a considerable amount of time not attending to what is happening around them. Safety may be compromised further by the cognitive demands associated with monitoring multiple feedback metrics. Research suggests that high levels of cognitive load can lead to mental fatigue (Dietrich & Audiffren, 2011), reduced reaction times (Holgado et al., 2019) and a decline in visual attention (Diekfuss et al., 2017). Cycling/triathlon coaches, as well as bike fitters have a duty to advise the athletes they work with on 'safe' practices both when training and competing (i.e., placement and visual display of cycling computers).

3. Implications for Bike Fitters

Bike fitting involves the biomechanical analysis and optimization of cyclist/triathletes' riding positions (Braeckevelt et al., 2019). A bike fit should incorporate a pre-fit interview to gather information on the rider's background and establish their goals; a pre-fit screening to assess strength and range of motion; and an initial on-bike biomechanical assessment. From this information, the bike fitter decides what interventions (i.e., strength training) and bike adjustments (i.e., saddle height, component choice, cleat positioning) should be implemented to best meet the rider's needs. Although the bike fitter should be receptive to the individual needs of the client there are recommendations/guidelines, based on empirical research, pertaining to joint kinematics (e.g., Holliday et al., 2017; Holliday & Swart, 2021). For example, it is recommended that knee flexion measured dynamically at the bottom of the pedal stroke during low intensity cycling should ideally be in the range of 33° - 43° (Swart & Holliday, 2019). These guidelines help to ensure that, even if adopting different fitting methods (e.g., static vs dynamic), bike fitters are aiming to set riders in positions that should reduce the likelihood of chronic injuries.

However, to the author's knowledge no standard or protocol has been put in place to establish whether a rider has an acceptable level of visibility in the position that has been set. In the absence of such a protocol, what constitutes an acceptable level of visibility becomes open to interpretation. The authors, as professionals working within the cycling industry, have seen a worrying trend whereby some practitioners are advocating to look down 'when it is safe to do so' and posting on social media platforms videos of athletes where vision appears to be severely impaired. Given the risk this presents to the athletes' safety, to advocate this as a position that the rider should adopt on the road is arguably negligent, even more so in situations where there is traffic (as in the case of Egan Bernal's crash). It is of the authors' opinion that adding the caveat 'when it is safe to do so' (as seen on some wind tunnel reports) does little to mitigate the safety concerns. Racing is unpredictable as obstructions (e.g., other riders, parked cars, barriers) may suddenly appear on a stretch of road that when reviewing the course may have been deemed as 'safe'. At 40 km/h an athlete is going to cover a lot of ground very quickly and have very little time to respond, particularly when intermittently adopting a head-down position.

Posting videos of this particular position on social media also creates challenges for other bike fitters who are not advocating this approach. Research has shown that social

media use is prevalent among athletes (e.g., Hayes et al., 2019). From experience, many athletes enter a bike fit appointment wanting to mimic the professional athletes they have seen on these platforms. As such, they possess preconceived ideas (which are sometimes incorrect) regarding what constitutes a fast, aerodynamic position. At times, it can be difficult for a bike fitter to dispel these ideas, that have become ingrained over many years, in the course of a 2 to 3 hour appointment. It may be that the rider does not fully heed the bike fitters advice once out on the road and has an accident/suffers an injury as a result of head-down riding. This raises the question of how bike fitters can safeguard themselves and ensure that when a rider leaves an appointment visibility in the position is good.

4. Recommendations for Future Research and Practice

The authors foresee that the trend of head-down riding and the adoption of unsafe time trial positions can be addressed by three means. The first involves establishing kinematic recommendations for bike fitters as to what constitutes a safe position with an acceptable level of visibility. This can be achieved by examining which kinematic variables (e.g., head inclination) correlate with visibility. Visibility can be assessed using eye tracking software, similar to that used in maritime, aviation, and automotive research (Martinez-Marquez et al., 2021; Novotný et al., 2022). This should prove a more reliable method than simply asking the athlete what they can see. If the athlete holds the belief that the head-down position is faster, this may serve to bias their response.

Athletes compromising their own safety in pursuit of success, both status- and financially-driven is not uncommon (Mazanov & Huybers, 2010). Research has found that between 5 and 31% of athletes have taken performance enhancing drugs (including anabolic–androgenic steroids, human growth hormone, and amphetamines), despite the threat these substances pose to the athlete's health and well-being (Momaya et al., 2015). Adopting an unsafe time trial position with limited visibility can be considered a similarly risky behaviour as ultimately it poses a risk to the athlete's wellbeing. As such, the second recommendation of this paper is to develop new equipment (i.e., helmet) which reduces the aerodynamic drag of the system as a whole (i.e., cyclist, wearables, and bike) when the rider adopts a safe position with an acceptable line of sight. This approach seeks to incentivize athletes to ride in safe positions by removing any perceived benefits of not doing so.

The final recommendation also relates to the principle of making 'safe' fast and involves reconsidering the current regulations regarding time trial positions. Despite the UCI recently updating the rules pertaining to time trial positions, Stefan Küng's crash demonstrates that this has done little to mitigate safety concerns. In an attempt to address the issue of head-down riding the UCI introduced three height categories which allow taller riders to utilise a higher hand position (UCI, 2023). Theoretically, this should reduce the gap between the head and the hands (i.e., improving aerodynamics) without the need to drop the head. Unfortunately, this change does not appear to have achieved its purpose of improving rider safety as evidenced in the case of Stefan Küng who by virtue of his height is eligible to utilise the higher hand position within the new UCI regulations. Perhaps a more successful approach would be to use the kinematic variables discussed above to provide a foundation on which to establish new regulations. These regulations would be evidence-based and would have involved an actual measurement of visibility as opposed to theoretical assumptions.

5. Conclusion

Due to a number of high profile crashes the safety of cycling time trial positions has been an area of considerable debate. Athletes are largely adopting unsafe riding positions in the hope of reducing aerodynamic drag. This presents significant challenges to bike fitters who have a duty of care to the athletes they work with along with a need to

safeguard their own professional practice. This paper presents three viable solutions to improving the safety of cycling time trial positions. The first step involves establishing kinematic correlates of visibility. These can then be used by bike fitters to ensure the positions that they are setting are safe, as well as in the development of new products, and the reevaluation of positional regulations. For this approach to be successful researchers, practitioners, governing bodies, and cycling manufacturers need to work together in the pursuit of improving the safety and wellbeing of athletes.

Conflicts of Interest: The authors declare no conflict of interest.

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