Investigating Novel Bicycle Braking Systems for Preventing Over-The-Handlebar Flips

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ABSTRACT

Objectives: Over-the-handlebar pitch-over is an unforgiving failure mode in bicycle braking, whereas automobile anti-lock brakes are designed to avoid wheel locking. This review discusses why the two-wheeled and four-wheeled vehicles' dynamics differ so dramatically for such a similar maneuver. It also evaluates the effectiveness of two concepts of bicycle braking systems that can prevent pitch-over: brake biasing and brake cable length extension.

Methods: The pitch-over threshold was established by equating the moment around the front contact patch due to the center of mass with the moment caused by the friction force at the rear wheel contact patch. It was then compared to the tire's adhesion limit to define the critical value at which the bicycle will either lock its wheels or pitch-over. Finally, the two considerations were analyzed using seven criteria: modulation, performance, safety, cost, mechanical/electrical complexity, and bicycle categories.

Results: A bicycle's pitch-over threshold depends solely on geometry, specifically the ratio between the horizontal distance from the front contact patch to the center of mass location and the center of mass height. For a typical bicycle, it means that the critical value is lower than the adhesion limit on dry pavement. In other words, a bicycle will always pitch-over before any of its wheels lock during the emergency stop. Brake biasing redistributes braking effort from front to rear wheels and is a logical choice for higher-end bicycles, such as e-bikes and mountain models, because it uses existing electronics in the braking system. Its performance is limited by the same physics that make bicycles dangerous, namely, the front wheel's normal force variation, which disappears entirely at the pitch-over threshold. Meanwhile, the brake cable length extension concept addresses the fundamental problem of compliance by allowing a longer throw before the maximum braking power is reached. It is a mechanically simple and cheap solution, which makes it ideal for lower- and mid-range bicycles, but it may sacrifice modulation and performance in a situation when the shortest possible stopping distance is necessary.

Conclusions: This review evaluated the effectiveness of two concepts of bicycle braking systems that can prevent pitch-over. Both of them provide a reasonable basis for future development, but neither is clearly superior to the other in any particular category. Instead, the choice between them is dictated by such factors as bicycle category, mechanical/electrical complexity, and cost.

Keywords: bicycle braking, pitch-over, wheel lock, brake force distribution, anti-lock braking systems, cyclist safety

INTRODUCTION

Background

In many places around the world, bicycles are widely used as a primary means of transportation. Though, there are many safety risks that come with bicycles. One common safety related issue arises from braking too hard on the front wheel, which can cause riders to lose control and flip over the handlebars. This contributes to the mechanics of the crash, causing serious injuries, including broken bones and concussions (Z. Ling et al., 2017).

In a report published by the Government of Canada in 2006, braking suddenly was listed in the category of Loss of Control, which was responsible for 3,234 injuries, or 81.0%. The Braking Suddenly circumstance was the 8th most common category, with 83 cases in total. This was made up of 22 from children, 46 from youth, and 15 from adults (Public Health Agency of Canada, 2017).

A report published by R. Utriainen in 2020 revealed that 5% of crashes were from braking maneuvers, but braking was also involved in many other crashes like avoidance of other road users. These braking maneuvers were mostly from the cyclist falling over the handlebar (R. Utriainen, 2023). When the bicycle comes to a halt, the cyclist's momentum is still moving forward at the same speed due to inertia. This results in a surge in force forward, shifting the center of mass around the front wheel's axle, as shown in Figure 1.

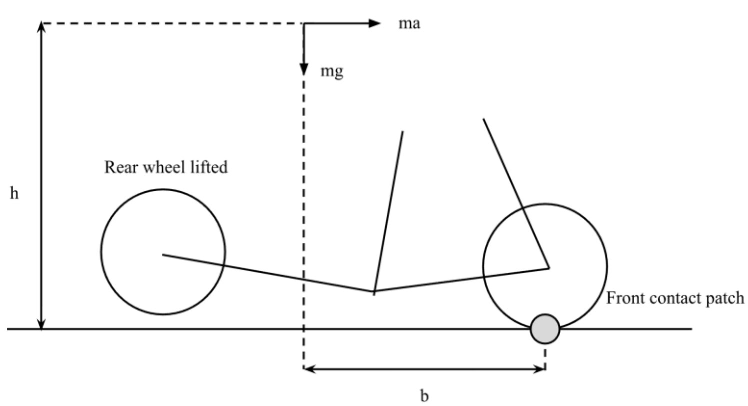

Figure 1. Free-body diagram of a bicycle and rider at the pitch-over threshold. The rear wheel just left the ground, so the normal reaction is at the front contact patch. The overturning moment from the inertial force ma about that point is balanced by the restoring moment from the weight mg (author's illustration).

When a large magnitude of force is applied to the front wheel, the load transfers forward until the rear wheel lifts and the system rotates about the front contact patch. This is a pitch-over, and it throws the rider over the handlebars. The deceleration thresholds have been established for motorcycles: the pitch-over for the 1985 Kawasaki Ninja was found to be higher than 1.0g by Frank et al. (2009) and Fatzinger et al. (2019) found the pitch-over of sport bikes to occur at approximately 0.98g. This is because a motorcycle's mass is located far lower and over a long wheelbase, while the bicycle rider sits far above the short wheelbase of the bicycle. This discrepancy is discussed in Section 2 where the threshold is derived based on this geometry.

In this paper, a review of recent and possible mechanical and electrical braking systems was conducted, including a brake biasing system that distributes brake force automatically or limits front braking and a brake cable length extension. Then, novel braking solutions were analyzed and evaluated through their stakeholders.

Context

Most modern bicycles use rim or disc brakes. Rim brakes slow the bicycle using rubber or metal pads that rub against the wheel rim, while disc brakes use rubber or metal pads to clamp onto a metal rotor attached to the wheel. More specifically, electronic bicycles normally use disc brakes as they are more effective at higher speeds and masses. Nevertheless, both brakes rely on driver input, making breaking a safety hazard during sudden stops.

To understand why more advanced braking technologies such as anti-lock braking systems (ABS) are used in cars but not bicycles, it is important to compare the fundamental braking differences between them.

Parameter	Bicycle Brakes	Car Brakes	Why important for ABS on bicycles
Brake Type	Rim or disc brakes	Disc brakes	ABS works better with hydraulic disc brakes like in cars/motorcycles because hydraulic pressure can be precisely controlled electronically. Rim brakes and cable-driven brakes are harder to modulate precisely.
Pressure Control	Cable tension or hydraulic fluid (pressure)	Hydraulic fluid (pressure)	ABS requires hydraulic systems for fast and precise pressure modulation. Bicycles using cable brakes can't easily be controlled by ABS.
Electronic Control	N/A	Distribution is electronically controlled	N/A

Table 1. Comparison of bicycle and car braking systems and Implications for ABS.

Two obstacles therefore stand between automotive anti-lock braking and bicycles. The first is implementation: cable-actuated and rim brakes cannot be modulated with the precision necessary to make all anti-lock hardware useful on a bicycle. The second, and more interesting difference, is that anti-lock brakes target the wrong failure mode. As Section 2 demonstrates, a bicycle reaches its pitch-over limit before its friction limit on dry pavement, meaning that a brake which only prevents lock has only addressed the lesser danger. This paper then explores control techniques which attempt to manage pitch, rather than slip.

The Pitch-Over Condition

A bicycle and a rider decelerating will transfer load forward onto the front wheel. The rear wheel lifts when its normal force reaches zero, and beyond that instant the system rotates about the front contact patch. Taking moments about that patch at the point of lift gives

$$mgb = mah \qquad \text{Eq. (1)}$$

Where:
m is the combined mass of bicycle and rider,
g is gravitational acceleration,
a is deceleration,
b is the horizontal distance from the front contact patch to the combined center of mass, and
h is the height of that center of mass above the ground.

Mass cancels, giving

$$gb = ah \qquad \text{Eq. (2)}$$

Thus, a heavier rider will reach the pitch-over at the same deceleration as a lighter one. A rider who shifts weight rearward and downward raises the threshold by increasing the b value and reducing h, which is quite normal to do (move back during hard braking).

Klug et al. report a critical deceleration of approximately 7 m/s^2, and dividing by acceleration due to gravity gives 0.71. So, the bike reaches pitch-over when it decelerates at about 71% of the acceleration due to gravity (for an instrumented trekking bicycle with an average adult rider in the unmodified seat post position) (S. Klug, 2017). This value is used as the representative bicycle pitch-over threshold throughout the rest of this paper.

Two Competing Limits of Deceleration

Deceleration is limited either by the point where the tire can no longer transmit the necessary force,

$$\frac{a}{g} = \mu \qquad \text{Eq. (3)}$$

Where μ is the coefficient of friction between the tire and the road surface.

Due to impending wheel lock, or the pitch-over limit, $\frac{a}{g} = \frac{b}{h}$, beyond which the rear wheel leaves the ground. Klug et al. define these two states, wheel lock and nose-over, as the physical limits of linear bicycle braking and use a point mass model with an empirically determined center of gravity to determine them (S. Klug, 2017).

Depending on the vehicle, one of the two limits is reached before the other, and the difference determines whether the vehicle is in danger of out-of-control rotation or loss of traction. A passenger car has its center of gravity low down and over a long wheelbase, meaning that b/h greatly exceeds the friction coefficient of dry pavement. The vehicle's tires reach their maximum adhesion before the pitch axis rotates, causing wheel lock to be the only possible failure mode. Thus, a driver of a car should use conventional anti-lock brakes. In contrast, a bicycle has a very high center of gravity over a short wheelbase, meaning that b/h is lower than the friction coefficient of dry pavement. The bicycle's rear wheel lifts before the front wheel reaches its maximum adhesion, and the failure mode is pitch-over instead of skidding tires. This difference in failure modes dictates the division between automotive and bicycle braking control strategies.

It is not a difference in brake hardware but rather in the dynamics of the two- and four wheeled vehicles that explains why automotive anti-lock systems have no bearing on contemporary bicycle safety technology. A system that prevents wheel lock cannot prevent pitch-over because, at the point of impending rotation, the front wheel still rolls on the road surface without sliding. To prevent pitch-over, an anti-lock brake system would have to detect imminent rotation and reduce front brake pressure before rotation begins. J. Skatulla et al. (2023) remark that, while such a strategy is theoretically viable, little research has been performed on the dynamics of bicycle pitching and skidding motion at the point where brake modulation can still prevent rotation.

METHODS

This study used qualitative research methods to investigate current and innovative bicycle braking systems for maximum safety through the problem of over-the-handlebar flips when too much braking force is applied on the front wheel. Existing braking systems such as mechanical disc brakes, hydraulic disc brakes, and rim brakes were researched to gain background knowledge for emerging braking systems such as brake biasing and brake cable length extensions. The research focused on how these novel braking systems can possibly work in bicycles and reduce the risk of rider instability during sudden braking. Lastly, the results were evaluated through a discussion of external factors such as modulation, different conditions, safety, cost, complexity and ease of implementation, and different bicycle types and target user groups.

RESULTS

Currently, there are two main brakes used in bicycles. These are disc brakes (mechanical or hydraulic) and rim brakes. Disc brakes are more efficient than rim brakes as rim brakes can slip due to environmental circumstances such as raining or snowing. Furthermore, disc brakes don't wear down as easily because they use hydraulics rather than pressure (O. Maier, 2017). Throughout this results section, solutions that can be implemented in disc brakes will be looked at.

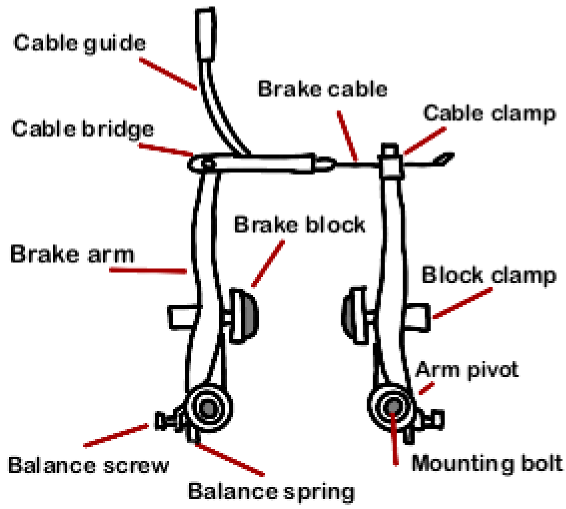

Figure 2. Parts of a rim brake. Tension pulls the brake arms together, pressing the brake blocks against the wheel's outer rim to create friction. (author's illustration).

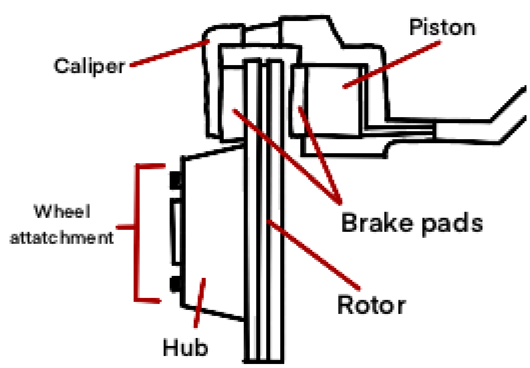

Figure 3. Parts of a disc brake. Piston inside the caliper squeezes brake pads against a rotor attached to the wheel hub. (author's illustration).

Brake Biasing

The first solution is brake biasing, where speed (hall effect) and pitch-based sensors are used to detect sudden deceleration or front lift and a proportional integral derivative (PID) control system to automatically reduce the front brake pressure. This reduces the pitch angle. This brake force distribution enables the braking force of each wheel to be independently controlled and makes each wheels' braking force proportional to their load. This effect is created through a sensor and controller. The sensors measure longitudinal acceleration, lateral acceleration, and vehicle pitch and load transfer for each wheel. Thus, when the sensors detect a lot of pressure on the front wheels and a sudden change in pitch, it knows that there is sudden braking. The principle is established in four-wheeled vehicles, since the electronic brake force distribution is proportional to braking with an instantaneous axle load. M. Nakazawa, et al. (1995) used these variables to mathematically model the dynamic load on each wheel and calculate how much braking force is proportional to each wheel's load. For example, if there is a lot more load on the front wheel, the back wheel will use the brakes more than the front wheel. M. Nakazawa et al.'s computer simulation and vehicle test showed that the braking distance and pitch-over was decreased, and that wheel lock only happened a few times; even then it was delayed. Nakazawa et al. have investigated a four-wheel vehicle in which the load transfer between the axles leaves ample room for rear braking. In order to adapt their solution to the case of a single-track vehicle, one should consider the steeper load transfer characteristics mentioned above. Bosch has developed a patent solution for a single-track vehicle by means of reducing front brake force based on a lift off indicator determined from the pitch angle and its time derivative, which is closer to the bicycle case than the automotive brake force distribution (Robert Bosch GmbH, 2024).

There are many benefits to this design. Since the sensors detect the angle of the bicycle instead of the braking pressure, it would remove false instances where the mechanism is triggered when there is a lot of braking pressure but the bicycle hasn't tipped over. This design could also be implemented if the bicycle leans backwards (when accelerating), too. It is easy to implement, works with rim and disc brakes, energy efficient, cost efficient, and lightweight. This could be a good solution for parents wanting to buy a bicycle that is safe for their children or for older people. Also, it is great for efficiency because it makes use of the back wheel too and only needs one lever for braking (not needing a lever to brake on the back).

Brake biasing has its limitations imposed by the same load transfer phenomenon which causes problems. The rear braking force is limited by the normal force acting on the rear wheels which decreases with increasing deceleration. This means that the rear brake reaches zero effectiveness (the so-called pitch-over point) at the very moment when the deceleration becomes maximal. Thus, brake biasing allows one to delay the moment of pitch-over but not to increase the maximal deceleration before it happens. What is actually achieved by introducing a biasing mechanism is the reduction of the probability of reaching the dangerous levels of deceleration altogether without having to reduce the maximal braking performance.

On the other hand, bumps or uneven roads could unexpectedly trigger the mechanism and the sensors and external weight shifter would have to be incorporated into the bicycle seamlessly or else it could disrupt the rider more than it helps them. This system is costly and complex because of the sensors and control systems. A power source would be needed, and it works mostly only with disc brakes. On top of that, the pressure control might overheat the braking system. Furthermore, the technical complexity and high maintenance requirements could be impractical for a casual rider. Lastly, this mechanism could be too complex for a casual rider (M. Nakazawa, 1995)

Brake Cable Length Extension

The second solution is a brake cable length extension. This is a spring-loaded piston system in a mechanical disc brake cable so if there is sudden brake force, it will temporarily extend the brake cable to prevent the bicycle from braking too suddenly.

Instead of having a rigid brake cable connecting the brake lever to the brake caliper, the spring-loaded piston unit makes it so that during gentle braking, the cable is normal (since the spring barely compresses). Then, when braking suddenly, the initial force will make the spring piston compress and extend a little bit before actually initiating the brake. Adding a spring in series with the cable results in decreased overall stiffness. For a given force on the lever, the pads will experience less clamp load until the point where the spring is fully compressed. This means that the rider must pull the lever further to achieve the same level of braking force than they would without the spring. The effect is a change in the relationship between lever travel and brake force instead of a time delay, which spreads the same range of braking force over a longer stroke. Peak braking force remains reachable; it simply sits further along the lever's travel. The stiffness of the spring and the length of the piston set how far.

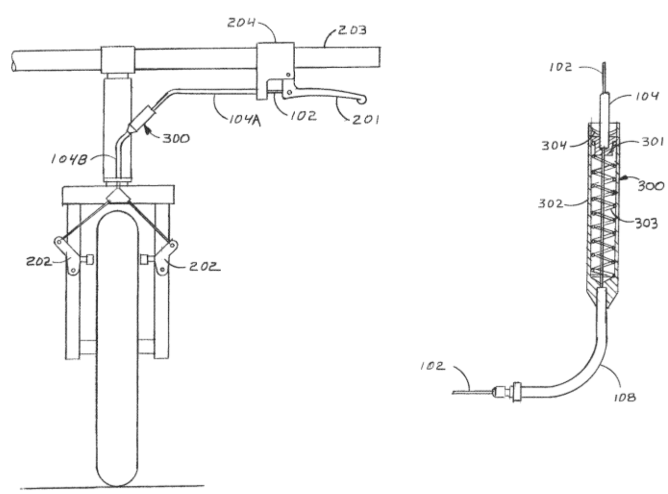

Figure 4. Brake cable length extension safety apparatus. On the left shows a front eye view of a bicycle wheel and how the brakes are connected. On the right shows the extended brake cable length in a housing coupled to a piston at the end of it (G. Ward and W. Hsieh., 2015).

The advantages of this solution are that there are no electronics or sensors, making it easy to produce. This can be implemented on bicycles not only as an add-on but incorporated into bicycles when they are being manufactured. This solution works with both rim and disc brakes, too.

The drawback of this solution is that in emergency situations when an immediate stop is necessary, the bike might not stop fast enough.

DISCUSSION

Both of these solutions are effective in preventing over-the-handlebar flips during sudden braking. However, their practicality differs depending on cost, complexity, and suitability for different types of riders and bicycles. This discussion evaluates the different aspects of these solutions and how these factors influence their suitability. The most important factor for a safe bicycle brake is controlled deceleration, or, in other words, decelerating without having over-the-handlebar flips. An ideal braking system must be able to do this while also taking into consideration many other factors: the rider's ability to control the amount of force, performance across different conditions, safety, cost, complexity, ease of implementation, different bicycle types, and target user groups.

Modulation: Modulation is how smoothly and precisely the rider can adjust their braking system. Both proposed solutions are automatic and don't include user input, but brake biasing is more reliable as the brake is the same force as a normal bike, except for the fact that it just spreads it across the front and back wheels. The brake cable length extension improves modulation, rather than making it worse. By distributing the same force range on a higher lever stroke, you get better fine control as each millimeter of lever displacement moves you less in terms of braking power. Of course, you need to move the lever further to reach max braking force, which may be a problem if you need to brake as quickly as possible. Recent work on bicycle ABS from Cheng C. Y. et al. (2025) show how important this is: electronically controlled valves can modulate brake pressure in 10-20 milliseconds, preventing wheel lock and improving stability.

Different conditions: Braking performance varies significantly depending on the conditions they are used in, for example weather and terrain. Wet conditions decrease the coefficient of adhesion of the tire. For μ below b/h, the limiting factor changes to the binding ceiling, and the pitch-over failure mode transforms into a wheel lock and skid. Brylev et al. (2021) evaluated bicycle deceleration on dry and wet asphalt while varying the braking system, the braking strategy, and the combined mass, and Lyubenov et al. provide deceleration and braking distance data for bicycles and an electric bicycle on multiple surfaces and conditions (I. Brylev et al., 2021). Thus, a pitch-limiting system would be the most beneficial on dry surfaces, and progressively less useful for worse conditions, for which standard anti-lock systems would be more useful. The two systems address different operating areas, and do not contradict each other. Dynamic analyses on bicycle braking on inclines show that weight transfer increases front-wheel load and highlights the importance of a more stable front-wheel braking system (D. Lie and C.-K. Sung, 2010). If the terrain is sloping downwards, the brake biasing would not be very useful as so much weight is already on the front wheel. In that case, the brake cable length extension would be a better solution.

Safety: Since the primary goal of these two solutions is to increase rider stability and enhance safety, it is important that the solutions themselves don't hinder the safety of the riders. Simulation and prototyping of a single-lever hydraulic brake with front-brake proportioning showed up to a 20% reduction in stopping distances in some scenarios, showing that automated biasing can improve safety (M. D. Machado et al., 2023). Brake biasing could be triggered through bumps or uneven roads, causing the rider to stop suddenly. Though, this risk is minimal and would only pose a hazard to riders with longer reaction times or reduced physical stability. In contrast, the cable length extension could be detrimental to emergency situations where you have to stop rapidly, for example, if you have to stop before you reach a car crossing across the intersection. Overall, both solutions have some rare safety issues.

Cost: Cost plays a major role in determining whether the two solutions can be widely adopted. As brake biasing is already implemented in four-wheeled vehicles and has been studied for motorbikes (M. H. Mahamad Basri et al., 2025), the control approach is not novel. However, the accelerometer, microcontroller, actuator, and other electronics would all be quite expensive. A full brake biasing system would require an accelerometer, microcontroller, and actuator in addition to the sensing and control electronics. Individual components in this class (IMU sensors, microcontrollers, small actuators) are available in similar form factors, and retail for approximately $5–50 range each, suggesting an assembled system could cost $100-250 in parts, although there are no known commercial products of this class to use as reference. However, these prices are expected to be reduced for volume production. For the cable length extension, only about 5-10 cm of housing and braking cable length would be needed. The extension is a much cheaper option. ABS would cost 10x to 20x more than this. Nonetheless, these options are costly. Detailed modelling of hydraulic disc brakes highlights the amount of specialized components for controlled pressure transmission, valves, sensors, and controllers and increase of cost (O. Maier, 2017).

Complexity and ease of implementation: Brake biasing is a lot more complex with its multitude of electronics. Studies on actuated and ABS-equipped bicycles show that controllers and feedback alone already require extensive modelling and electronics and are far more complex than brake cable length extension (C.-Y. Cheng et al., 2024). On the other hand, the brake cable length extension is very simple because it is implemented inside of the already-existing brake housing. For these reasons, the cable length extension can be installed much easier onto existing bicycles.

Different bicycle types and target user groups: All of these factors change when considering different bicycle types. First, for regular bikes, the two solutions can be implemented, but only a small user group would be interested in using it, in particular people of older age or parents wanting to keep their children safe. They would also be more common on shared bikes because these bikes are used a lot in urban settings and by less experienced riders. Mountain bikes require precise rider control, so the cable length extension wouldn't be a good choice. Brake biasing would be a better choice for mountain bikes. Thus, electronic bikes (ebikes) would be the best choice for these two braking systems. Analyses of hydraulic disc brakes for e-bikes emphasize that their higher mass and common use of advanced hydraulic systems make implementing the systems not much of a difference to the weight of the bike and don't have much of an emphasis on simplicity and cost. Although both solutions would work effectively on ebikes, the brake cable length extension only works for mechanical disc brakes, excluding the more popular hydraulic and pressure-based disc brakes (S. Klug, 2017).

This research investigated existing and innovative bicycle braking systems to evaluate how effectively they minimize the amount of over-the-handlebar flips during sudden braking. After analyzing how brake biasing and brake cable length extensions work and the key factors relevant to their implementation, the two novel braking systems i) brake biasing and ii) brake cable length extension are both viable options. Though, brake biasing was found to be more useful for higher-end bikes, such as ebikes, as the electronics needed are already there and the technology is available. Because of this reason and the fact that it still allows for fast braking, brake biasing bikes would be extremely effective in reducing the risk of over-the-handlebar flips for not only ebikes but also mountain bikes. However, this would make these bikes a lot more complex and expensive. On middle to lower end bikes, brake cable length extensions are found to be more effective due to their low cost and easy setup. The trade-off is that the fastest stop possible would take longer to reach. Future work should focus on simulation, prototyping, and controlled experimental testing to quantitatively evaluate braking performance and rider stability outcomes.

REFERENCES

Brylev IS, Evtyukov SA, Blinder MM, Cherepnina TY, Rogov VR. 2021. Factors affecting the formation of the established deceleration of two-wheeled vehicles. IOP Conf Ser Mater Sci Eng. 1159:012058. doi:10.1088/1757-899X/1159/1/012058

Cheng CY, Saputra I, Shi CE, Wang CH. 2024. Efficiency enhancement of bicycle anti-lock braking systems (ABS): design and optimization of solenoid actuators through finite element analysis and performance simulation. Adv Mech Eng. Sep;16(9). doi:10.1177/16878132241281238

Fatzinger E, Landerville J, Bonsall J, Simacek D. 2019. An analysis of sport bike motorcycle dynamics during front wheel over-braking. SAE Technical Paper 2019-01-0426. doi:10.4271/2019-01-0426

Frank T, Smith J, Hansen D, Werner S. 2009. Motorcycle rider trajectory in pitch-over brake applications and impacts. SAE Int J Passeng Cars Mech Syst. 1(1):31–42. doi:10.4271/2008-01-0164

Klug S, Moia A, Verhagen A, Görges D, Savaresi SM. 2017. Effectiveness of actuating on rectilinear bicycle braking dynamics. IFAC-PapersOnLine. Jul;50(1):972–979. doi:10.1016/j.ifacol.2017.08.173

Lie D, Sung CK. 2010. Synchronous brake analysis for a bicycle. Mech Mach Theory. Apr;45(4):543–554. doi:10.1016/j.mechmachtheory.2009.11.006

Ling Z, Cherry CR, Dhakal N. 2017. Factors influencing single-bicycle crashes at skewed railroad grade crossings. J Transp Health. Feb;7:54–63. doi:10.1016/j.jth.2017.01.004

Lyubenov D, Kadirova S, Kadikyanov G, Kolev Z, Topchu D. 2024. Experimental determination of bicycles and electric bicycle stopping distance. Eng Proc. 70:26. doi:10.3390/engproc2024070026

Machado MD, Viswanathan VK. 2023. Design and characterization of a single lever bicycle brake with hydraulic pressure proportioning. Appl Sci. Jan;13(3):1767. doi:10.3390/app13031767

Mahamad Basri MH, Ismail NI, Pahmi A, Rabilah R, Sharudin H. 2025. Design explorations on the brake force distributions of a motorbike. J Appl Eng Des Simul. Mar;5(1):66–74. doi:10.24191/jaeds.v5i1.100

Maier O, Györfi B, Wrede J, Arnold T, Moia A. 2017. In-depth analysis of bicycle hydraulic disc brakes. Mech Syst Signal Process. Oct;95:310–323. doi:10.1016/j.ymssp.2017.03.044

Nakazawa M, Isobe O, Takahashi S, Watanabe Y. 1995. Braking force distribution control for improved vehicle dynamics and brake performance. Veh Syst Dyn. Jun;24(4–5):413–426. doi:10.1080/00423119508969101

Public Health Agency of Canada. 2017. Injuries associated with bicycles — 2006, ages 1 year and older. Ottawa (ON): Government of Canada. [accessed 2026 Jan 25]. https://www.canada.ca/en/public-health/services/injury-prevention/canadian-hospitals-injury-reporting-prevention-program/injuries-associated-bicycles-2006-ages-1-year-older.html

Robert Bosch GmbH. 2024. Method and device for preventing a forward flip-over of a single-track motor vehicle. US Patent 11,866,021. 2024 Jan 9.

Skatulla J, Maier O, Schmidt S. 2023. Instrumented bicycle for experimental investigation of braking dynamics including front brake induced rear wheel lift up. Evol Sch BMD 2023. 5th ed. doi:10.24404/63fe5c46c9d7c3ebc76e944b

Utriainen R. 2020. Characteristics of commuters' single-bicycle crashes in insurance data. Safety. Feb;6(1):13. doi:10.3390/safety6010013

Ward GA, Hsieh W, inventors. 2015. Brake safety apparatus. US Patent 9,334,012 B1. 2015 Feb 12.