UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

CPSC/OFFICE OF THE SECRETARY

2003 JUN 19 A 11:28

VOTE SHEET

DATE: JUN 12 2003

TO: The Commission
Todd A. Stevenson, Secretary

THRU: W.H. DuRoss, III, General Counsel
Stephen Lemberg, Assistant General Counsel for Administrative Law

FROM: Lowell F. Martin, Attorney-Advisor, GCAL (ext. 7628)

SUBJECT: Petition Requesting Mandatory Performance Standard for Bicycle Handlebar Ends (HP 01-1)

VOTE SHEET

The attached staff briefing package recommends that the Commission deny petition HP 01-1 requesting a mandatory performance standard for bicycle handlebar ends. The petitioner stated as the basis for her request that bicycle handlebar ends that cannot satisfy such a standard pose a serious risk of trunk injuries, particularly to young children. The staff recommends denial on the basis that available data on specific contact points on the handlebars and the mechanics of the event, such as rider speed at the time of the incident, angle of the rider's impact with the handlebar end, and the force of that impact, are insufficient to support development of a mandatory performance standard and that this information would be difficult, if not impossible to obtain through further study.

Please indicate your vote on the following options.

I. DENY PETITION HP 01-1 AND ISSUE THE DENIAL LETTER AS DRAFTED.

______________________________ (Signature)

______________________________ (Date)

NOTE: This document has not been reviewed or accepted by the Commission.
Initial ________ Date 6/12/03

CPSA 6 (b)(1) Cleared 6/12/03
No Mfrs/PrvtLblrs or
Products Identified
Excepted by
Firms Notified,

II. DENY PETITION HP 01-1 AND ISSUE THE DENIAL LETTER WITH REVISIONS. (PLEASE SPECIFY.)

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(Signature) (Date)

III. GRANT PETITION 01-1 AND DIRECT STAFF TO PREPARE A DRAFT ADVANCE NOTICE OF PROPOSED RULEMAKING FOR COMMISSION CONSIDERATION.

(Signature) (Date)

IV. TAKE OTHER ACTION. (PLEASE SPECIFY.)

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____

____

(Signature) (Date)

Attachment: *Briefing Package: Bicycle Handlebars, Petition HP 01-1*, June 2003

BRIEFING PACKAGE

BICYCLE HANDLEBARS

PETITION HP 01-1

June 2003

For Further Information Contact:

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ATTACHMENTS

Tab A Petition for regulation of bicycle handlebars from Flaura Koplin Winston, M.D., Ph.D., Director, TraumaLink: The Interdisciplinary Pediatric Injury Control Research Center, The Children's Hospital of Philadelphia, December 28, 2000.

Tab B Memorandum from Elizabeth W. Leland, EC, "Petition HP 01-1: Bicycle Handlebar Performance Standard," April 17, 2003.

Tab C Memorandum from Debra Sweet, EPHA, "Memo for Handlebar Petition," September 9, 2002.

Tab D Memorandum from Jason R. Goldsmith, Ph.D., HS, "Petition HP01-1, Petition for Bicycle Handlebar Performance Standard," November 5, 2002.

Tab E Memorandum from Vincent J. Amodeo, ESME, "Petitioner's Claim of Feasibility for Reducing Handlebar Injuries; HP 01-1, Petition for Bicycle Handlebar Performance Standard," May 29, 2003.

Tab F Memorandum from Troy Whitfield, ES, "Petition HP 01-01 — Petition for Handlebar Performance Standard," April 23, 2003.

EXECUTIVE SUMMARY

On December 28, 2000, Flaura Koplin Winston, M.D., Ph.D., of the Children's Hospital of Philadelphia, petitioned the U.S. Consumer Product Safety Commission (CPSC) to "regulate the safety of handlebars by way of a performance standard regarding energy dissipation and distribution during impact." The petitioner is concerned about serious injuries to abdominal organs that occur when young children contact the end of bicycle handlebars during low-speed falls from bicycles.

The Commission published a notice in the Federal Register on February 14, 2001, requesting written comments about the petition from interested persons. The comments received by CPSC primarily reported handlebar incidents or discussed handlebar design. Forty-one of the 42 comments specifically supported standards for bicycle handlebars. Huffy Bicycle Company requested that the Commission postpone a decision on the petition until the ASTM International Task Group for Bicycle Handlebars and Stems investigates the feasibility of a voluntary standard. A voluntary standards activity was initiated in November 2001 and the Task Group plans to have a draft standard by November 2004.

Based on the NEISS data for 2001, there were an estimated 5,042 children, ages 2 through 17 years old, who visited emergency departments for bicycle handlebar-related injuries to their chest, abdomen, or pelvis (trunk area). These injuries represented 1.4 percent of all bicycle injuries in 2001. Because the specific point of contact is not often reported in NEISS, the number of children who received injuries as a result of contact with the end of the handlebar, or any other specific point of contact, is an unknown subset of the bicycle handlebar-related injuries.

In addition to cases reported through NEISS, the Commission received reports of 147 incidents where a child was struck by, or fell onto, a bicycle handlebar during the period January 1, 1991 to June 1, 2002. Twenty-four of the 147 incidents specifically state that the injuries resulted from contact with the end of the handlebar.

Over the same 11-year period, CPSC received reports of eight children who died after handlebar-related incidents. It was specifically reported that the child struck the end of the handlebar in two of the incidents.

The petitioner submitted a research paper describing a design concept for retractable handlebar ends to demonstrate that "safer handlebars are feasible. " The petitioner claims that the retractable handlebar design will reduce the number of injuries by reducing the impact force by approximately 50 percent. The technical staff concluded that this claim has not been validated in the material submitted by the petitioner. Therefore, the petitioner has not adequately demonstrated that the basic approach of retractable handlebar ends will address the reported injuries in a quantifiable manner.

Based on an analysis of the available information, the staff recommends that the Commission deny the petition for a mandatory performance standard for bicycle handlebars. The available data substantiate the potential for serious injury or death as a result of contact with the handlebars during a fall from a bicycle. However, the staff believes that the data on specific contact points on the handlebars and data on the mechanics of the incidents are insufficient to support a recommendation for a mandatory rulemaking proceeding. Further, the staff does not believe that this information could be obtained through additional study.

While it may be difficult to support a recommendation for a mandatory rulemaking proceeding, the staff believes that improved design and performance requirements for handlebars could help reduce the number and severity of injuries. The CPSC technical staff will continue to work with the Task Group for Bicycle Handlebars and Stems to explore the feasibility of addressing the risk of injury associated with contacting the handlebars during a fall from a bicycle.

United States
CONSUMER PRODUCT SAFETY COMMISSION
Washington, D.C. 20207

MEMORANDUM

JUN 12 2003

TO : The Commission
Todd A. Stevenson, Secretary

THROUGH : W. H. DuRoss, III, General Counsel
Patricia Semple, Executive Director

FROM : Jacqueline Elder, Assistant Executive Director for Hazard Identification and Reduction
Barbara J. Jacobson, Directorate for Health Sciences
(301) 504-7305
Debra Sweet, Directorate for Epidemiology
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SUBJECT : HP 01-1, Petition for Bicycle Handlebar Performance Standard

The staff prepared this briefing package in response to Petition HP 01-1. The package discusses product and market information, bicycle handlebar-related deaths and injuries, the petitioner's design concept for retractable handlebar ends, current standards for bicycle handlebars, and comments received in response to the Commission's February 14, 2001, notice in the Federal Register requesting comment on the petition.

BACKGROUND

Petition HP 01-1
(Tab A)

On December 28, 2000, Flaura Koplin Winston, M.D., Ph.D., of the Children's Hospital of Philadelphia, petitioned the U.S. Consumer Product Safety Commission (CPSC) to regulate bicycle handlebars. She petitioned CPSC to "regulate the safety of handlebars by way of a performance standard regarding energy dissipation and distribution during impact."

Dr. Winston submitted an article, "Hidden Spears: Handlebars as Injury Hazards to Children," *Pediatrics* 1998;102:596-601, to support her assertion that serious injuries to abdominal organs occur when young children contact the handlebars during a fall from a bicycle. The article states that the end of the handlebar acts as a blunt spear, causing the injuries upon impact. In addition, the article includes the following statement: "This injury mechanism may be avoided through bicycle redesign that would involve both limiting rotation of the front wheel and modifying the ends of handlebars." Dr. Winston also submitted a research paper, "Protecting the Child's Abdomen: A Retractable Bicycle Handlebar," in support of the petition. This paper, since published in 2001, describes a handlebar end that is designed to retract and absorb the forces transmitted to the abdomen on impact (*Accident Analysis and Prevention*; 33:753-757).

In her petition Dr. Winston states, "Our handlebars dissipate the impact energy and spread the forces over a larger surface area so that forces transmitted by the end of the handlebar to the abdominal organs during impact are reduced to below known injury tolerance levels. We are not suggesting that our design is the optimal design for safer handlebars; rather, we are demonstrating by our design that safer handlebars are feasible and should be required on all new bicycles and that retrofit solutions for existing bicycles should be explored."

PRODUCT AND MARKET INFORMATION
(Tab B)

Product Description

A rider uses the bicycle handlebars to control the steering and balancing of the bicycle. The bicycle handlebar is attached to the frame by the handlebar stem. A bicycle handlebar is classified by the industry as a "bicycle component." Other components including handlebar grips, bar ends, brake levers, and gearshift levers sometimes are attached to the handlebars. Bicycle frame manufacturers and bicycle assemblers purchase components to make new bicycles. Consumers can also purchase components to change, upgrade, or repair their bicycles.

Handlebar grips or end caps, also known as end plugs, often cover the bare metal ends of the handlebar. Generally the end caps are made of metal or hard plastic. Bar ends are components that are attached to the ends of the handlebar in a tilted upright position; they give the rider an additional gripping surface which can help lessen fatigue and provide a better body position for climbing hills.

Bicycle Sales

Mass merchandise stores are the primary distribution channel for bicycles. The bicycles sold in these department and discount stores are primarily imported from China.

Bicycles sold by independent bicycle dealers are more expensive and are generally of higher quality. Imported as well as domestically manufactured bicycles are sold in these stores. Full-line sporting goods stores are a third distribution channel for bicycles.

Ninety-eight percent of the bicycles sold in the United States in 2000 were imported. Sales of bicycles that year reached a high of nearly 20.6 million units. About 90 percent or more of the bicycles sold in the U.S. had riser, high-riser, or flat handlebars. Other types of handlebars include drop, aero, moustache, bull moose, and recumbent. Types of bicycles and handlebars are shown in the Appendices of Tab B. The various configurations for children's bicycles are described in the following table:

CHILDREN'S BICYCLES			
Type of Bicycle	**Type of Handlebar**	**Wheel Diameter**	**Gears**
BMX (Bicycle Moto-Cross) or Dirt	High-Riser	20", 24"	Single
Trail or Light-Duty Mountain	Riser, High-Riser, or Flat	20", 24"	Multiple
Juvenile or Youth	High-Riser	10", 12", 16", 20", 24"	Single
Freestyle or Trick	High-Riser	20"	Single
Jumping	Flat or High-Riser	20"	Single
Miniature and Circus	Flat (Miniature)	6"	Single

Bicycle Use

The results of a national survey of U.S. bicycle riders conducted in 1998 showed that an estimated 85.3 million people, ages 2 to 75, rode bicycles that year. About 38 percent of all riders, or 32 million, were under 16 years old.

Comparing all age groups, riders under the age of 16 rode their bicycles most frequently, with an average riding time of about 300 hours for the year. Riders in this age group rode most frequently on sidewalks, playgrounds, and neighborhood streets with low traffic volume.

CPSC INCIDENT DATA
(Tab C)

The petitioner is concerned primarily with addressing injuries to abdominal organs as a result of a child contacting the end of the handlebar during a fall from a bicycle. This section expands the discussion to include other types of injuries and other points of contact on the handlebars.

Deaths

Over the 11-year period, January 1, 1991, to June 1, 2002, the Commission received reports of eight children who died after bicycle handlebar-related incidents. All of the deaths were due to severe abdominal injuries. The children who died ranged in age from 4 to 17 years old. Seven of the eight children were male. None of the cases mention involvement of a motor vehicle. It was specifically reported that the child struck the end of the handlebar in two of the incidents. While the other six deaths were caused by similar injuries, the point of contact on the handlebar was not reported.

During the same 11-year period, 19 children died of injuries to the trunk after a bicycle-related incident. Contact with the handlebar was not reported for these incidents. However, because of the similarities in the injuries, it is possible that some or all of these deaths resulted from contact with the handlebar during a fall from a bicycle.

2001 NEISS Injury Estimates

Based on data from the CPSC National Electronic Injury Surveillance System (NEISS), there were an estimated 352,244 children, ages 2 through 17 years old, who visited emergency departments for all bicycle-related injuries in 2001.

In an estimated 5,042 of the incidents, it was specifically reported that the child received an injury to the chest, abdomen, or pelvic region (trunk area) after contacting the bicycle handlebar. This estimate is based on information reported in the NEISS data field for recording a brief summary of the incident scenario. Bicycle handlebar injuries to the trunk area represented 18.6 percent of all bicycle injuries to the trunk area and 1.4 percent of all bicycle injuries in 2001. The average and median age of the children injured in the trunk area by contacting the handlebar was 10 years old; 79 percent were male.

Approximately 92 percent of the 5,042 children who received trunk injuries as a result of contact with the handlebar were treated and released from the hospital the same day. Approximately 8 percent (430) of the 5,042 children were transferred to another facility for further treatment, held at the hospital for observation, or admitted to the hospital. These 430 children were treated for contusions, abrasions, lacerations, internal organ injuries, and other injuries.

Because the specific point of contact on the handlebar was generally not reported through NEISS, it is not possible to provide estimates for injuries associated with specific points of contact on the handlebar. Based on past experience, staff believes that a NEISS special study, even including follow-up telephone and on-site investigations, may not provide the level of detail needed to provide the basis for injury estimates. It is particularly difficult to obtain reliable information about the specific point on the handlebars that was contacted during a fall from a bicycle. Additionally, information on the mechanics of the incident, such as rider speed, angle of impact, and force of impact is seldom, if ever, available following an incident.

Handlebar-Related Incidents Reported to CPSC

In addition to cases reported through NEISS, the Commission received reports of 147 incidents where a child was struck by, or fell onto, a bicycle handlebar over the 11-year period, January 1991 through June 1, 2002. Some of the cases provide detail about the incidents including the type of handlebars, condition of the handlebars, the point of contact, and the severity of the injury. However, these data are anecdotal and cannot be used to suggest trends or calculate estimates.

Handlebar-Related Injuries to the Trunk Area

Eighty-two of the 147 reported handlebar incidents resulted in injuries that involved the child's trunk area. The children who were injured were 3 to 16 years of age with a median age of 9 years. Sixty-two of the children were males and 20 were females.

Some of the children received multiple injuries (89 injuries in 82 reported incidents). There were 42 serious injuries to major organs in the abdomen and chest - spleen (12), liver (11), gastrointestinal tract (10), kidney (4), pancreas (2), heart (1), lung (1), and hernia (1). Twenty-one additional injuries were contusions. Eighteen injuries were reported as abdominal trauma or injury. Six children received injuries to their pubic region, and two were injured in their hip or pelvic region.

It was reported that the child contacted the handlebar end in 12 of the 24 incidents where the contact point was reported. The type of handlebar was "high-rise" in 18 of the 21 incidents where the handlebar configuration was described. This type of handlebar is found on BMX and other types of children's bicycles. For three incidents the type of handlebar was "flat." This type of handlebar is primarily found on trail or light-duty mountain bicycles.

Other Handlebar-Related Injuries

Sixty-five of the 147 reported handlebar incidents resulted in injuries that did not involve the child's trunk area. The children ranged in age from 3 to 15 years and the median age was 8 years old. Fifty-two of the children were males and 13 were females.

Forty-three of the 65 non-trunk injuries were not serious. These injuries included contusions and lacerations to the face, legs, hands, and feet. There were 14 reports of serious injury. Three children with serious injuries were impaled or punctured by the handlebar (neck, thigh, body part is unknown). Four children received concussions as a result of hitting their heads on the handlebar. Four children suffered fractures to their arms, wrists or fingers. One child had a finger amputated when the handlebar fell on it. One child suffered damage to his eye and tear duct. One child's injuries included fractured cheekbones, a fractured nose, a detached lip, and black eyes. In addition, some of this child's teeth were knocked out.

It was reported that the child contacted the handlebar end in 12 of the 15 incidents where the contact point was reported. The type of handlebar was "high-rise" in 12 of the 14 incidents where the handlebar configuration was described. For two incidents the type of handlebar was "flat."

Injuries (Trunk and Non-Trunk) resulting from contact with the handlebar ends

Twenty-four of the 147 incidents reported to the Commission from January 1991 through June 1, 2002, specifically state that the injuries resulted from contact with the end of the handlebar. In 20 of the 21 incidents where the handlebar condition was reported, the metal end of the handlebar was exposed. The injuries include fractures, lacerated organs, and lacerations to other body parts including the leg, head, face, finger, abdomen, groin, eye and toe. In one incident the child had internal injuries, including a lacerated liver, even though the handlebar grip was intact.

While the data on these incidents are limited, the injuries do not appear to be associated with a specific combination of variables. The incidents involve children ranging from 5 to 13 years of age. Similar injuries occur when children are riding their bicycles normally and lose control and when they are performing stunts. The type of handlebar was "high-rise" in 8 of the 11 incidents where the handlebar configuration was described. For three incidents the type of handlebar was "flat."

HEALTH SCIENCES INJURY ASSESSMENT
(Tab D)

The medical literature cites cases and studies of injury to abdominal organs as a result of contact with bicycle handlebars. Collision with the handlebar (any contact point) has the potential to produce minor injuries such as bruises, abrasions, and lacerations, or more serious injuries such as lacerated organs in the chest and abdomen. The more serious injuries may require surgery and are potentially fatal. As observed in the medical literature, impact with the handlebars can produce the following traumatic abdominal injuries:

- gastrointestinal
- pancreatic (pancreas)
- splenic (spleen)
- hepatic (liver)
- renal (kidney)
- abdominal herniation (hernia)
- traumatic arterial occlusion
- transection of the common bile duct
- rupture of the abdominal aorta

Proper and prompt diagnosis of abdominal organ injury is of critical importance. Injuries may appear minor upon first examination due in part to the lack of external signs of injury (i.e. bruising or other skin disruptions). However, patients seen and dismissed with minor injuries may return hours or days later with what is then recognized as a severe injury. In other cases, individuals do not seek medical attention until they are critically ill.

Each type of abdominal organ injury reported in the medical literature is discussed in Tab D. Where details are available, information such as handlebar style, location on the handlebar where impact occurred, presence or absence of handlebar end caps or handle grips, and the medical treatment required is included. In some cases, involvement of the handlebar end can be surmised based on the nature of the injury (e.g. external markings and very concentrated internal injury of an abdominal organ from blunt trauma).

The incidents that appeared to involve contact with the handlebar end, and those where the point of contact was known to be the handlebar end, indicate flat, riser, and high riser handlebars are involved. These handlebars are designed for bicycling with an upright posture and are found on most types of children's bicycles.

Some of the serious abdominal injuries discussed in the literature involved handlebars that were missing end caps or handlebar grips, devices that normally cover the bare metal end of the handlebar. However, the presence of end caps or handlebar grips does not prevent the occurrence of blunt traumatic injuries to the abdominal organs. There are specific references in the medical literature about blunt trauma injury resulting from covered handlebar ends. For example, in separate incidents, children had a lacerated kidney, a lacerated liver, a lacerated spleen, and a traumatic hernia of the abdominal wall as a result of falling on covered handlebar ends.

ENGINEERING SCIENCES ASSESSMENT OF THE PETITIONER'S RETRACTABLE HANDLEBAR DESIGN (Tab E)

The petitioner requests the Commission to regulate the safety of bicycle handlebars by establishing a performance standard for energy dissipation and distribution during impact. To demonstrate the feasibility of safer handlebars, the petitioner and her colleagues present a concept for retractable handlebar ends. The claim is made that the retractable handlebar design will reduce the number of injuries by reducing the impact force by approximately 50 percent.

Engineering Sciences (ES) staff has evaluated the proposed design concept and has concluded that the petitioner has not adequately demonstrated that the basic approach of retractable handlebar ends will address the reported injuries in a quantifiable manner. Modifications to the handlebar design were developed on the basis of a single accident scenario in which a rider hits an obstacle that immediately stops the forward motion of the bicycle, and to regain balance, the rider turns the handlebar perpendicular to his/her abdomen. The rider continues forward due to momentum, impacts the end of the handlebar, and maintains contact until the opposite end of the handlebar impacts the ground.

ES staff believes this is an oversimplification of the dynamics of the many possible crash scenarios and therefore cannot be relied upon as a description of the only sequence of events that is likely to occur. The forces used by the petitioner both in evaluating the injury potential, and in designing the telescoping mechanism, are based on this scenario. This point is important in assessing whether the proposed mechanical device would address the injuries. If the orientations of the rider and handlebar and ground are different than assumed by the petitioners, then the forces will be different from those calculated.

The motion of the proposed device is limited to compression along the axis of the handlebar end. The device will only telescope in relation to the angle between the direction of the force and the axial direction of the end of the handlebar. An impact with the end of the handlebar, but not in alignment with it, could well generate enough force to cause injury. ES staff believes that cases are likely to occur with impact at some significant angle to the axis of the handlebar, and even if the telescoping end collapsed, the forces involved would be significantly different from the design assumption.

The researchers cite values for the compressive tolerance of the pediatric liver and spleen from the medical literature (Sturtz, 1980) and use these values in the force calculations. The staff is concerned about the reliability of these values because they are each based on a sample of one. In addition, the values are based on large contact area loads applied to organs removed from cadavers, not point loads applied to the abdominal region of living tissue as would be the case in an incident. Further, the researchers indicate that the current design would not prevent injury to the spleen. Therefore, the staff believes that the values cited in the Sturtz paper are of little comparative value to the handlebar analysis.

The proposed device is a spring-mass-damper system intended to retract upon impact to absorb the majority of the energy. Each end of the handlebar system would contain such a device. When a child impacts the handlebar end during a crash, the spring in the damper system would compress. The analysis does not account for the fact that the child's abdomen will also compress during impact. The technical staff believes that the amount of compression of the abdomen that occurs before the device compresses may well be enough to cause injury. Further, in order for the spring in the handlebar to retract upon impact with the relatively soft abdomen, its spring constant would have to be low. This could result in a handlebar that may not be stable enough to support normal steering loads, presenting stability hazards to a rider.

The petitioner indicates that this is only a prototype and that further work would need to be done to optimize the system. The petitioner discusses changing spring rates and damping grease, but ES staff believes it is unlikely that any one combination of spring and grease could account for all possible scenarios. Variations in rider speed, size, weight, bike configuration, angle of impact, impact surface, etc. would make it difficult to optimize one retractable handlebar design that would be suitable for all situations.

CURRENT STANDARDS FOR BICYCLE HANDLEBARS
(Tab F)

There are no mandatory or voluntary standards in the U.S. that address the risk of injury associated with contact with the end of the handlebar during a fall from a bicycle. There is an international standard for bicycles for young children that has some requirements that address the risk of injury associated with contact with the end of the handlebar.

Mandatory Standards in the U.S.

There is a mandatory bicycle standard in the Federal Hazardous Substances Act (FHSA) regulations, 16 CFR Part 1512, which became effective in 1976. This standard sets safety requirements for reflectors, wheels and tires, chains, pedals, braking and steering systems, and for structural components such as frames and forks. The requirements for the steering system at §1512.6(c) specify the position of the handlebar ends to assure comfortable and safe control of the bicycle. Section 1512.6(d) requires the ends of the handlebars to be capped or covered. End-mounted devices such as handlebar grips and end plugs must pass a performance test to assure that they will withstand a removal force of about 15 pounds.

International Standards

There is an international standard for bicycles for children from about 4 years to 8 years old, ISO 8098. Similar to the FHSA, this standard requires the ends of the handlebars to be fitted with handlebar grips or end caps that will withstand a specified removal force. A 1992 amendment, ISO 8098:1989 (E), requires the handlebar grips or caps to be made of resilient material and to have an enlarged end with a minimum diameter of 40mm (1.57 inches). This amendment was added to help assure that the metal ends of the handlebars do not become exposed and to help reduce the likelihood of serious injury if a handlebar end is contacted. The ISO standard also has a requirement that the steering shall be free to turn through at least 60 degrees but not more than 75 degrees either side of the straight-ahead position.

Voluntary Standards in the U.S.

There is an ASTM International voluntary standards Subcommittee on Bicycles (ASTM F08.10). This Subcommittee has a Handlebars and Stems Task Group (ASTM F08.10.1). On November 6, 2001, the staff wrote a letter to the Task Group Chairman asking the group to consider developing voluntary performance standards for handlebars. During their November 2001 meeting, the Task Group voted affirmatively to respond to the staff's request. In a letter dated December 13, 2001, the Task Group Chairman provided a summary of its proposed scope of work and a preliminary schedule. The Task Group decided to address "spearing type injuries, caused by the end of the handlebar impacting into the abdominal and pelvic areas." The Task Group also decided to limit the scope to "single speed bicycles, with 20-inch wheels or smaller and riser (BMX style) handlebars." The Task Group plans to have a written standard for vote by November 2004.

In a letter dated February 8, 2002, CPSC staff sent additional information to the Task Group. This included relevant in-depth investigations, incident reports, and comments received in response to the February 14, 2001, Federal Register notice. The staff asked the Task Group to consider expanding its scope to include children's bicycles with wheels 24" or smaller regardless of the handlebar configuration or whether they have single or multiple speeds. An expanded scope would include trail or light-duty mountain bicycles that have riser, high-riser, or flat handlebars and multiple speeds.

CPSC staff attended a Task Group meeting on May 8, 2002. The Chairman of the Task Group reviewed the CPSC staff request to expand the preliminary scope of the work. Some members did not support expanding the scope because of concerns that different handlebar configurations may require different solutions. With CPSC staff concurrence, the Task Group decided to begin with the limited scope as defined at their November 2001 meeting. The Task Group agreed to consider expanding the scope to other sizes and types of children's bicycles in the future. The Task Group clarified that their use of the terminology "spearing type injuries" was not meant to limit the scope to penetrating wounds resulting from exposed metal handlebar ends. They also acknowledged the CPSC staff view that an effective solution to address the risk of blunt trauma to abdominal organs would require more than a requirement for intact handlebar grips and end caps.

At the Task Group meeting held on November 7, 2002, the members voted to table most of their current backlog of activities in order to concentrate on the handlebar issue. The Task Group Chairman suggested two possible approaches to address handlebar-related injuries: filled handle bar ends to prevent "cookie cutter" type punctures, and limited handle bar rotation for 20" bicycles. One task group member passed around a prototype handle bar grip with an expanded diameter designed to provide some deflection under a compressive or side load.

At the Task Group meeting held on May 7, 2003, there was further discussion about permanent caps for the handlebar ends and about the need for increasing the diameter of the handlebar ends to address blunt trauma injuries. An important consideration is the durability of the materials used. Members will try to determine the basis for the diameter of handlebar ends specified in the current ISO bicycle standard. A draft recommendation will be circulated to the Task Group members for comment. The next meeting will be held in October 2003.

FEDERAL REGISTER NOTICE

The Commission published a notice in the Federal Register on February 14, 2001, soliciting written comments about the petition from interested persons. The comment period was extended to May 16, 2001, in response to a request from Huffy Bicycle Company (Huffy).

The Commission received 36 comments in response to the Federal Register notice and six additional comments after an article written by Deirdre Van Dyk about retractable handlebars was published in the December 2001 issue of *Popular Science*. Copies of all comments are available from the Office of the Secretary. Forty-one of the 42 comments support standards for bicycle handlebars. The comment from Huffy requests that the Commission postpone a decision until the ASTM Task Group investigates the feasibility of a voluntary standard.

Comments Regarding Incident Data

Many of the comments are from physicians, surgeons, and other medical professionals and describe bicycle handlebar-related incidents that were treated at the children's hospital or trauma center where they work. Other comments are from parents or relatives of children who were seriously injured in a bicycle handlebar-related incident.

A comment about incidents was also received from Huffy, a leading supplier of bicycles to the U.S. market. Huffy is a member of the ASTM International Subcommittee on Bicycles, F08.10 and also the Handlebar and Stem Task Group, F08.10.01. Huffy does not believe that the petition or other available evidence supports amendments to the current mandatory performance standards for bicycles.

Huffy also states that the available NEISS data do not appear to allow one to quantify the frequency for abdominal injuries caused by the rider being speared by the handlebar ends during a sudden turn of the front wheel.

The petitioner and her colleagues from TraumaLink, Children's Hospital of Philadelphia, and individuals from the Center for Injury Research and Control, University of Pittsburgh, provided preliminary data regarding national annual estimates of serious bicycle handlebar-related injuries and associated costs. Their data was published as a journal article in September 2002, "Estimates of the Incidence and Costs Associated With Handlebar-Related Injuries in Children," *Archives of Pediatric Adolescent Medicine* 2002;156:922-928.

Based on the 1997 19-State Hospital Discharge Database, the petitioner estimates that each year 1,040 children 19 years and younger suffer serious abdominal or pelvic organ bicycle-related injuries that require hospitalization. The petitioner further estimates that 894 of these children are injured as a result of contact with the handlebar. The proportion of handlebar-related injuries to all bicycle injuries was based on 56 children admitted to the Children's Hospital of Philadelphia for abdominal or pelvic injuries between 1996 and 2000.

CPSC Staff Discussion of Comments about Incident Data

The types of abdominal injuries reported by the petitioner, found in the medical literature, and described in the comments, are consistent with those in the anecdotal handlebar-related incidents reported to CPSC. However, as pointed out in Huffy's comment, it is not possible to use NEISS data to quantify the total number of bicycle-related incidents of specific concern to the petitioner. Because the specific point of contact is not often reported in NEISS, the number of children hospitalized for serious internal organ injuries as a result of contact with the end of the handlebar is an unknown subset of the bicycle handlebar-related injuries.

The staff believes the petitioner's estimates may lack statistical validity because the data are based on a group of hospitals that may not be representative of the nation as a whole. In addition, because the Children's Hospital of Philadelphia is a trauma center, and was also known to be collecting data on handlebar-related incidents, the proportion of handlebar-related injuries to all bicycle injuries could be greater than that of hospitals in general. Furthermore, the petitioner does not provide estimates for incidents related to contact with any specific point on the handlebar, including the end of the handlebar.

Comments Regarding Handlebar Design

An engineer wrote that he finds the petitioner's retractable handlebar end to be an "impractical, expensive" solution to the problem. He commented, "It holds the possibility of causing as many injuries as it is intended to prevent, by potentially compromising control of the bicycle." He suggested that alternative solutions include modifying the handlebar configuration, limiting the handlebar rotation, and adding larger diameter, padded end plugs. He believes the overall bicycle design should consider the placement of gearshift levers, bar ends, and other attachments that may injure a rider during a fall from a bicycle.

A consultant on bicycle-related safety issues noted that bicycle handlebars, stems, and some shift levers pose a significant safety hazard in virtually all bicycle fall and collision modes because they are the components most likely to be struck by vulnerable body parts during a fall or collision.

> To the extent that an amendment to the mandatory standard is appropriate, Huffy does not believe that the retractable handlebar design advocated in the petition is necessary for addressing the potential hazard. Huffy agrees that the problem identified in the petition is worthy of more study and that the ASTM International F08.10 Handlebar and Stem Task Group intends to consider whether standards to address injuries sustained from faulty or failed end-plugs

would be the appropriate response. Huffy expresses concern that the retractable spring-loaded handlebar ends proposed by the petitioner could be more susceptible to mechanical failure or could be less stable and compromise rider control. Huffy comments that control is of particular concern for bicycles used for off-road and stunt riding such as mountain or BMX bikes. Huffy suggests that handlebar-related injuries that do not involve contact with the handlebar ends would be better addressed by more frequent use of pads or other cushioning devices for the crossbar or handlebar stem.

CPSC Staff Discussion of Comments about Handlebar Design

As discussed in detail in the engineering assessment, the staff also has concerns about the petitioner's design concept. It is clear that the intended function of the proposed device is to absorb energy upon impact, thus averting some of the injury potential under a given set of circumstances. However, the staff questions the basis for the petitioner's calculations and the assumptions made about contact with the handlebar during a fall. In addition, the petitioner's concept is primarily intended to address injuries associated with contact with the end along the axis of the handlebar. At other angles of impact the device may not retract sufficiently to prevent injury, if at all.

The staff agrees with Huffy that addressing injuries resulting from contact with exposed metal handlebar ends is supported by the incidents reported to CPSC. However, the staff also notes that the medical literature shows that the presence of end caps or handlebar grips alone does not always prevent serious injury to abdominal organs. The staff supports further efforts to explore means to mitigate serious injuries associated with handlebar impact.

OPTIONS

A. Grant the petition.

If the Commission determines that bicycle handlebars may present an unreasonable risk of personal injury and that a mandatory rule is reasonably necessary to eliminate or reduce the risk, the Commission could grant the petition and direct the staff to prepare a draft advance notice of proposed rulemaking (ANPR).

B. Deny the petition.

The Commission could deny the petition on the basis of one or both of the following reasons:

- The Commission determines that the available information does not support a finding that bicycle handlebars may present an unreasonable risk of personal injury.
- The Commission determines that there is insufficient information to support a mandatory rulemaking proceeding and it is unlikely that the necessary information could be obtained.

C. Defer a decision on the petition.

If the Commission determines that there is insufficient information to make a decision on the petition, but that such information could be obtained, the Commission could defer a decision and direct the staff to obtain additional information.

CONCLUSIONS AND STAFF RECOMMENDATION

Based on an analysis of the available information, the staff recommends that the Commission deny the petition for a mandatory performance standard for bicycle handlebars. The available data substantiate the potential for serious injury or death as a result of contact with the handlebars during a fall from a bicycle. However, the staff believes that the data on specific contact points on the handlebars and data on the mechanics of the incidents are insufficient to support a recommendation for a mandatory rulemaking proceeding.

The staff often conducts NEISS special studies in order to collect additional detail about product-related incidents. If the data are sufficient, the staff is able to develop injury estimates for specific hazard scenarios. In this case, the staff does not recommend further study. Even with on-site investigations it is difficult to obtain reliable information about the specific point of contact on the handlebars associated with an injury.

Additionally, information on the mechanics of the incident is seldom, if ever, available following an incident. The staff believes that variations in rider speed, size, weight, bike configuration, angle of impact, impact surface, etc. would make it difficult to optimize one retractable handlebar design that would be suitable for all situations. Given the range of unknown variables about handlebar-related incidents, the level of potential effectiveness of the petitioner's device cannot be accurately estimated.

While it may be difficult to support a recommendation for a mandatory rulemaking proceeding, the staff believes that improved design and performance requirements for handlebars could help reduce the number and severity of injuries. The ASTM International consensus process provides an opportunity to develop such requirements. The CPSC technical staff will continue to work with the Task Group for Bicycle Handlebars and Stems to explore the feasibility of addressing the risk of injury associated with contacting the handlebars during a fall from a bicycle.

TAB A

The Children's Hospital of Philadelphia

34th Street and
Civic Center Boulevard
Philadelphia, Pa. 19104-4399
215-590-1000

December 18, 2000

Ann Brown
Chairman
United States Consumer Product Safety Commission
Washington, DC 20207-0001

RE: **Petition for regulation of bicycle handlebars**

Dear Ms. Brown,

I am writing to alert you to a potentially preventable form of serious injury – handlebar-related injuries to abdominal organs. It has long been known that bicycle handlebars pose a risk of pancreatic, intestinal, renal, liver, and splenic injuries, particularly to young children. Our recent study demonstrates that these serious injuries occur in the setting of minor incidents – falls from bicycles not involving motor vehicle crashes. (see attached manuscript) The discordancy between the minor circumstances (low-speed falls) and the serious nature of the injuries suggest that the cause of the injury was the bicycle itself. We further explored the circumstances and discovered that the handlebars were acting as blunt spears and, as such, were causing the injuries upon impact.

Our further research indicates that handlebars can be designed that will minimize the risk of these injuries. (see attached manuscript) Our handlebars dissipate the impact energy and spread the forces over a larger surface area so that forces transmitted by the end of the handlebar to the abdominal organs during impact are reduced to below known injury tolerance levels. We are not suggesting that our design is the optimal design for a safer handlebars; rather, we are demonstrating by our design that safer handlebars are feasible and should be required on all new bicycles and that retrofit solutions for existing bicycles should be explored.

By this letter, I am petitioning the Consumer Product Safety Commission to regulate the safety of handlebars by way of a performance standard regarding energy dissipation and distribution during impact.

Thank you in advance for your thoughtful consideration of this very important issue.

Sincerely,

Flaura K. Winston

Flaura Koplin Winston, MD. PhD

Director,
TraumaLink: The Interdisciplinary Pediatric Injury Control Research Center
The Children's Hospital of Philadelphia

Assistant Professor, Pediatrics
The Children's Hospital of Philadelphia and the University of Pennsylvania School of Medicine

Hidden Spears: Handlebars as Injury Hazards to Children

Flaura K. Winston, MD, PhD*‡, Kathy N. Shaw, MD, MS*‡, Allyson A. Kreshak, BA*, Donald F. Schwarz, MD, MPH*‡, Paul R. Gallagher, MA*, and Avital Cnaan, PhD*‡

ABSTRACT. *Objectives.* To delineate the mechanism of serious bicycle handlebar-related injuries in children and make recommendations for preventive strategies.

Methods. Prospective cross-sectional surveillance system of seriously injured child bicyclists supplemented by in-depth, on-site crash investigation to delineate specific injury mechanisms. Interdisciplinary analyses involved engineers, clinicians, epidemiologists, and biostatisticians.

Setting. The emergency department and in-patient trauma service of an urban level one pediatric trauma center between October 1995 and September 1997.

Participants. Patients under 18 years of age who were treated for serious bicycle-related injuries (Abbreviated Injury Scale scores of 2 or greater).

Results. The surveillance system identified two distinct circumstances for serious child bicyclist injury: 1) handlebar-related injuries associated with minor incidents (falls from bicycles) and 2) nonhandlebar-related injuries associated with severe incidents (bicycle-motor vehicle crashes). Crash investigations explored the minor incidents that resulted in serious handlebar-associated injuries. In the typical mechanism, as the child lost control of the bicycle and began to fall, the front wheel rotated into a plane perpendicular to the child's body. The child then landed on the end of the handlebar resulting in serious truncal injuries.

Conclusions. A discordancy exists between the apparently minor circumstances and serious injuries sustained by child bicyclists who impact bicycle handlebars. Recognition of the mechanism of handlebar-related injuries might aid the practitioner in early diagnosis of serious abdominal injuries in child bicyclists. This injury mechanism may be avoided through bicycle redesign that would involve both limiting rotation of the front wheel and modifying the ends of handlebars. An integrated approach involving a surveillance system to identify an injury hazard supplemented by in-depth, on-site crash investigations effectively provided the detailed mechanism of injury needed to develop interventions. *Pediatrics* 1998;102:596–601; *bicycle, handlebars, children, abdominal trauma, injury prevention, injury mechanism.*

ABBREVIATIONS. ICE, Injury Circumstance Evaluation; EMS, Emergency Medical Services; AIS, Abbreviated Injury Scale; ISS, Injury Severity Score; MAIS, Maximal AIS.

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Received for publication Jul 22, 1997; accepted Mar 18, 1998.

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PEDIATRICS (ISSN 0031 4005).

A primary goal of injury control research is to develop interventions that will reduce the incidence and severity of injuries. The process of translating research into interventions involves identifying injury hazards and elucidating the etiology of the hazard in sufficient detail for those who will develop the interventions. Application of this process has resulted in the identification of head injury as a significant source of morbidity and mortality in child bicyclists and resulted in the development of the bicycle helmet.[1–6]

Recent reports[7–9] indicate handlebars as another source of injury among child bicyclists even among low-speed crashes.[7] Effective countermeasures, however, have not yet been developed primarily because of the limited understanding of the injury mechanism. The majority of reports of handlebar-related injuries have been limited to descriptions of treatment strategies, operative techniques, and course of recovery. Impact with handlebars has been documented as producing traumatic abdominal wall hernia;[10–13] renal, intestinal, liver, splenic, and pancreatic injuries;[7–9,14–17] abdominal wall rupture;[18] abdominal aorta rupture;[19] transection of the common bile duct;[20] traumatic arterial occlusion;[21] groin injuries;[22,23] and even death.[24] Underlying organ injuries are often occult, as external bruising is infrequently present, and the signs and symptoms of organ injury do not present for hours.[7] Although these reports have recognized the role of the handlebar in child bicyclist injury, there is insufficient information regarding the detailed mechanism of injury.

For effective interventions to be developed, the mechanism of handlebar-related injury must be understood. In the current study we proposed to 1) identify the basic circumstances surrounding child bicyclist injuries through use of a surveillance system and 2) elucidate the detailed mechanism of injury with on-site, in-depth crash investigations incorporating the expertise of engineers, epidemiologists, clinicians, and biostatisticians.

METHODS

Injury Circumstance Evaluation (ICE) Study of Bicyclists, Pedestrians, and Motor Vehicle Occupants

The goal of the ICE Study is to identify significant injury hazards to children and to elucidate the mechanism of the injury hazard with sufficient precision to allow the development of interventions. To achieve this goal, the ICE Study combines a prospective, cross-sectional surveillance system of injured children and on-site, in-depth crash investigations to identify specific injury mechanisms. Previous results of the ICE Study revealed the mechanism of airbag-related deaths and serious injuries in children.[25-27]

The ICE Study recruits pediatric patients <18 years of age who were transported by Emergency Medical Services (EMS) personnel and treated for injuries sustained as bicyclists, pedestrians, or motor vehicle occupants at a level one urban pediatric trauma center servicing a five-county region. Excluded from the ICE Study are children for whom a history cannot be obtained. Consent for inclusion in the study is obtained according to a protocol approved by the Institutional Review Board of The Children's Hospital of Philadelphia.

The ICE surveillance system incorporates data collected from self-administered surveys completed by EMS personnel upon delivery of injured children to the emergency department and surveys administered by two trained parahealth professionals to children, witnesses, and relatives upon the child's admission to the inpatient trauma service for treatment of his or her injuries. For a given child, multiple respondents complete surveys to obtain the most complete history. Discordant responses are resolved by follow-up interviews. Surveys were developed by incorporating the expertise of engineers, clinicians, and epidemiologists through the approach of biomechanical epidemiology.[28] Biomechanical epidemiology is a new concept that combines the strengths of engineering, medicine, and epidemiology through the design, execution, and analysis of injury research.

The ICE surveillance system is analyzed to identify circumstance-injury patterns. Cases representing these patterns are then subjected to on-site, in-depth crash investigation by Dynamic Science, Inc, (Washington, DC) a professional crash investigation team. Data collected by the investigators include scene and vehicle evidence and child bodily contact points that are used to determine how the injury event occurred and the kinematic movement of the child in response to the event. These data are analyzed independently by two professional investigators to elucidate detailed mechanisms of injury.

Reconstruction of the injury-producing events involves standardized procedures that relate scene and vehicle evidence to the injuries received by the child. Differences in interpretation are resolved by a third investigator. Protocols are available on request.

Descriptions of the injuries sustained are obtained from the medical record and coded according to the *International Classification of Diseases, 9th Clinical Modification*[29] and Abbreviated Injury Scale (AIS) codes (see definition below) by two separate individuals (trained research assistants), one of whom is blinded to injury mechanism. Discrepancies are resolved by joint review of the medical records. Additional information obtained from the medical record includes gender and age.

The AIS[30] and the Injury Severity Score (ISS)[31] were used to classify bicyclist injury severity: The AIS rates the severity of an anatomic injury from 1 (minor injury) to 6 (fatal injury) for each of six body regions: head/neck, face, chest, abdomen, extremities/pelvic girdle, and external. A score of 0 was assigned to patients who sustained no injuries. Because multiple injuries might occur within one or several body regions, Maximal AIS (MAIS) was defined for each body region and overall for any body region and was recorded for each subject. All subjects in this study had a MAIS of ≥2. The ISS was developed to account for overall injury severity. ISS is the sum of the squares of the three highest AIS scores, thereby accounting for multiple injuries sustained.

ICE Surveillance Data Collection for the Current Study

The subjects for the current study were the subset of the ICE Study population who were seriously injured bicyclists (AIS ≥2) treated at our regional trauma center. Only those more seriously injured children were included because they constitute a well-defined population who are triaged to the center for definitive trauma care.[32,33]

As mentioned, the ICE Study uses a series of surveys to obtain detailed trauma histories that describe the injury circumstances. Answers used in the current study involve time of incident, descriptions of the sites of body impact, bicycle crash type (eg, struck and thrown on motor vehicle), direction of impact and fall, surfaces impacted, speed of vehicles, and other circumstance information. Specific questions addressing handlebar involvement in injury included anatomical descriptions of where the handlebars made impact with the child's body and what object the child's body first made impact. The questionnaire is available from the authors on request.

Child bicyclists were systematically classified into two impact groups based on survey responses. The handlebar group was composed of those whose survey responses indicated that they made impact with the handlebar. The remaining bicyclists were classified into the nonhandlebar impact group.

Survey responses were systematically classified into three event severity categories. Bicyclist collisions with a moving motor vehicle were classified as severe; bicyclist collisions with a stationary object (eg, pole or parked vehicle) or another bicyclist were classified as moderate; bicyclist collisions in which the child simply fell off the bicycle were classified as minor.

Statistical Analyses

Gender was compared between the two impact groups (handlebar and nonhandlebar) by a Fisher's Exact test. Age was compared using a Student's t test for independent samples. Distribution of the most severely injured body regions was compared using an exact χ^2 test. MAIS and event severity were compared between impact groups using a Kruskal–Wallis Exact test. ISS was compared between impact groups using a Mann–Whitney U test. Analyses were conducted using SPSS and StatXact. Statistical significance was set at $P < .05$.

On-site, In-depth Crash Investigations for the Current Study

Analysis of the surveillance data identified minor bicycle-related incidents resulting in serious injuries. Cases with this discordant circumstance-injury pattern for which a bicycle was available for inspection and consent was obtained were identified for targeted study using on-site, in-depth crash investigations for the determination of injury mechanisms. Specialized data collection forms were developed to record scene, vehicle, and injury data for injured child bicyclists and were used for the current study.

RESULTS

From October 1995 through September 1997, 107 bicyclists with MAIS 2 or greater injuries were identified from the ICE Study and formed the cohort of seriously injured child bicyclists for the current study. Over half (59%) of the 107 children in the study had multiple injuries. Overall, the 107 children in the study sustained a total of 190 injuries. These injuries were distributed by body region as follows: 46 head/neck injuries, 7 facial injuries, 5 chest injuries, 18 abdominal injuries, 61 extremity injuries, and 53 external/superficial injuries.

The distribution of the most severely injured body region for each child based on handlebar impact grouping is presented in Table 1. The handlebar impact group is comprised of children with injuries distributed among most body regions, but the majority of serious injuries occurred within the abdominal region. The nonhandlebar impact group had injuries distributed among all body regions, but the most severe injuries were to the extremities and head ($P < .0001$).

The abdominal injuries in the handlebar impact group were as follows: six splenic lacerations, two liver lacerations, three kidney injuries (two lacerations and one hematoma), and two pancreatic lacerations. Other handlebar impact-related injuries included one pneumothorax, one thigh impalement, one closed head injury with basilar skull fracture, and one radius fracture.

The distribution of demographic variables, MAIS, ISS, and event severity between the two impact

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TABLE 1. Distribution of Most Severe Injuries by Impact Type of Injury

Body Region	Handlebar Impact	Non-handlebar Impact	Total*	P Value
Head/neck	1	29	30	<.0001
Face	0	1	1	
Chest	1	1	2	
Abdomen/pelvis	13	3	16	
Extremities	2	47	49	
External	0	1	1	
Equivalent head and face†	0	1	1	
Equivalent head and chest†	0	1	1	
Equivalent head and extremity†	0	6	6	

* The 107 bicyclists represented had multiple injuries, but the body region corresponding with the most severe injury a bicyclist sustained was used for this table.
† Categories represent body regions which sustained the same injury severity and were equivalently the most severely injured body regions.

groups is presented in Table 2. Overall, the majority of injured bicyclists were male (78%) and the average age was 10 years. There were no significant differences in gender and age for the handlebar impact and nonhandlebar impact groups. The handlebar and nonhandlebar impact groups had similar severities of injury as demonstrated by similar MAIS and ISS ($P = .51$ and $P = .28$, respectively). Median MAIS and ISS were 2 (range, 2–4) and 5 (range, 4–16), respectively, in the handlebar impact group and 2 (range, 2–5) and 5 (range, 4–34), respectively, in the nonhandlebar impact group.

There was a significant association between the event severity and impact group ($P < .0001$). No severe events (bicycle-motor vehicle crashes) resulted in handlebar impact; rather, the more minor events (falls from bicycles) were associated with handlebar impact.

Thirteen (76.5%) of the handlebar impact-related crashes occurred as a result of five minor crash types: 1) when the bicyclist lost balance after hitting a discontinuity in the riding surface (sidewalk pothole, grass-sidewalk interface, or curb), 2) when the child braked suddenly, 3) after the chain disengaged from the wheel (chain pop), 4) during a performance of a stunt, or 5) when the rider suddenly turned the front wheel. The four remaining handlebar impact-related crashes occurred under moderate crash circumstances in which the rider made impact with a stationary object or other bicyclist.

In both minor and moderate circumstances, upon falling from the bicycle, the child made impact with the handlebar end, the stemcrown (Fig 1), or crossbar (Fig 2). In 12 (70.6%) of the cases, the child made impact with the end of the handlebar. Two made impact with the stemcrown or crossbar. In the remaining three specific handlebar impact was unknown.

Surveillance data regarding handlebar-related injuries were confirmed and supplemented by in-depth, on-site crash investigations. Seven cases of handlebar-related injury were selected for investigation because the bicycle was available for inspection and consent was obtained. Events investigated included three bicycle mechanical failure, two loss of control, and two stunts. All of the bicycles were appropriately sized for the riders. Four subjects impacted the handlebar ends; 1 subject impacted the stemcrown; 1 subject impacted the crossbar; and 1 subject impacted either the handlebar end, the crossbar, or both. Five of the bicycles were stunt-type; two of which were self-assembled with parts from a variety of bicycles. The handlebars on the five stunt-type bicycles were regular handlebars with an exaggerated curvature toward the rider. The handlebars on the other two bicycles were the same regular handlebars with less curvature toward the rider. Protective rubber covering was present on six of the handlebar ends; none had shock-absorbing foam padding on the handlebar ends. One bicycle had exposed metal handlebar ends (Fig 3). The stem-

TABLE 2. Patient Frequency and Injury Characteristics by Impact Type

Variable	Handlebar Impact	Non-handlebar Impact	Total*	P Value
Gender				
Male	14	69	83	0.76
Female	3	21	24	
Age (y)				
Mean	10	10.4	10.34	0.58
SD	3	3.3	3.21	
MAIS†				
2	9	56	65	0.51
3	6	26	32	
4	2	7	9	
5	0	1	1	
Median	2	2		
Range	2–4	2–5		
ISS‡				
Median	5	5		0.28
Range	4–16	4–34		
Event Severity				
Minor (Fall)	13	18	31	<.0001
Moderate (Other collision)	4	17	21	
Severe (Motor vehicle collision)	0	55	55	

* 107 bicyclists are represented.
† Represents the most severe injury a bicyclist sustained.
‡ Represents overall injury severity.

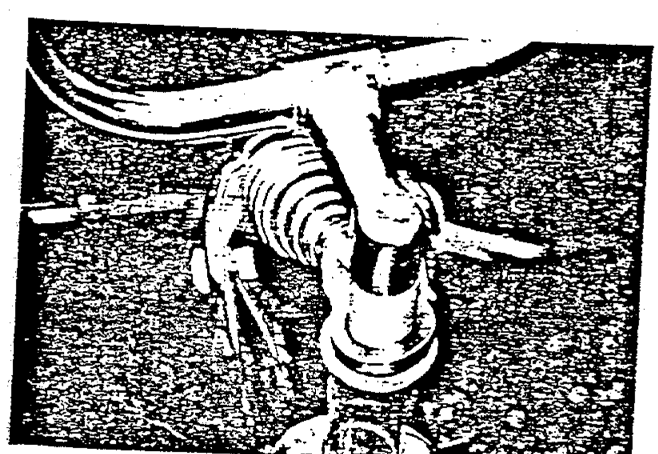

Fig 1. Stemcrown onto which a bicyclist fell resulting in a pancreatic fracture.

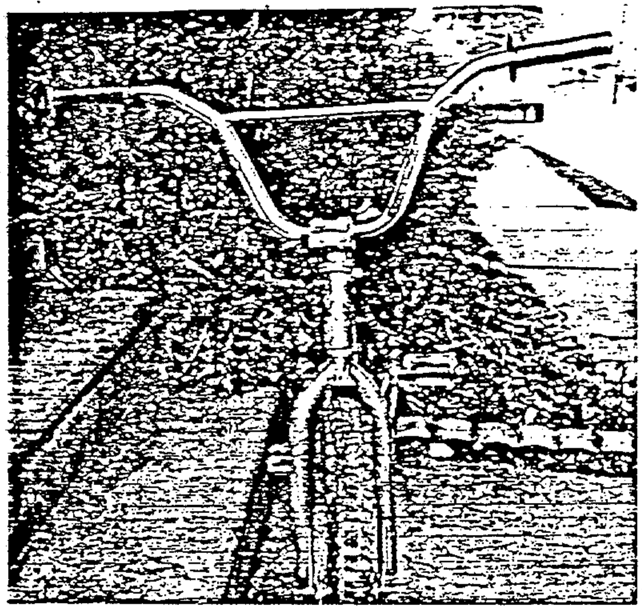

Fig 2. Crossbar onto which a bicyclist fell, resulting in a flail chest and pneumothorax.

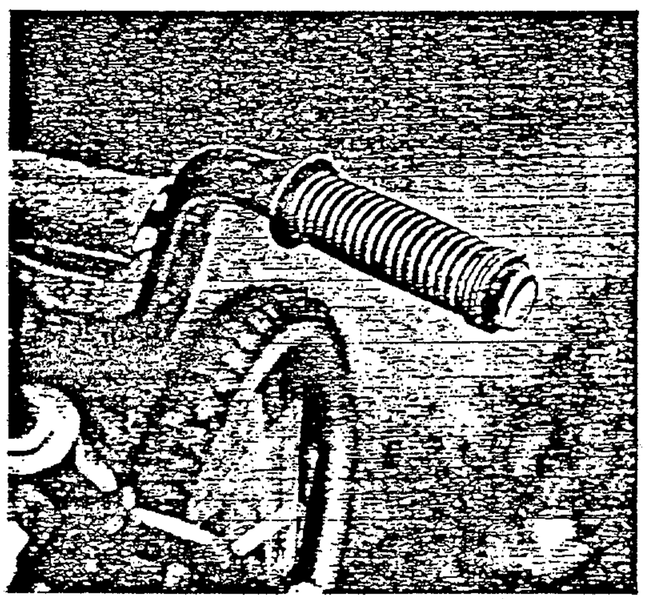

Fig 3. Exposed metal handlebar end onto which a bicyclist fell resulting in a liver laceration.

crown (Fig 1) and crossbar (Fig 2) onto which two of the bicyclists fell were not protected or padded.

One mechanism of injury was common to four of the seven bicyclists: one stunt rider, two bicyclists who lost control, and one whose bicycle sustained mechanical failure. As the child began to fall, the front wheel rotated into a plane perpendicular to the child's body. The child then landed on the end of the handlebar and serious truncal injuries resulted. The injuries sustained included two liver lacerations, one renal laceration, and one splenic laceration. None of these involved penetration of the skin and five of the seven bicyclists had external bruising.

In two cases of mechanical failure, the child fell and landed on the crossbar or stemcrown. Injuries sustained included a flail chest with pneumothorax and a pancreatic fracture, respectively. In the case involving a rider performing a stunt, it could not be determined if the impact was with the crossbar or the handlebar end. In this case, a splenic laceration resulted. A typical case of impact with the handlebar end is presented below.

A 6-year-old boy arrived at our hospital via interhospital helicopter transport for treatment of a liver laceration. The child was riding his stunt bicycle at 4 miles per hour when his bicycle hit a discontinuity in the sidewalk. As the front tire began to cross the concrete-grass interface, the child lost momentum, causing the front wheel to turn toward the right exposing the child's abdomen to the right handlebar, whose end was exposed rusted metal (Fig 3). He subsequently lost his balance and fell onto the right handlebar; together the bicycle and child fell to the ground. The child then lay at rest until a neighbor came over and helped him.

The child's mother called the pediatrician and described her son's abdominal pain. The pediatrician advised the mother to give her son acetaminophen and call back in a couple of hours. Disregarding the physician's advice, she brought her son to a local emergency department where an abdominal computed tomogram revealed a liver laceration that virtually transected the right and left hepatic lobes. He was immediately transferred by helicopter to The Children's Hospital of Philadelphia.

On arrival at our hospital, his heart rate was 124, respiratory rate was 32, and his blood pressure was 129/68. His Glascow Coma Score was 15 and his trauma score was 15 (−1 respiratory rate). On admission, he was febrile and the physical examination revealed a tender, distended abdomen. Laboratory studies were significant for hemoglobin of 10 g/dL (nL: 11.5–15.5 g/dL), sodium of 152 mmol/L (nL: 136–142 mmol/L), potassium of 3.32 (nL: 3.8–5.0 mmol/L), ionized calcium of 1.12 mmol/L (nL: 1.15–1.34 mmol/L), plasma glucose of 205 mg/dL (nL: 65–121 mg/dL), and albumin of 2.2 g/dL (nL: 3.5–5.2 g/dL). He was initially admitted to the pediatric intensive care unit, but because of tachycardia he was fluid-resuscitated and brought to the operating room where he received 3000 mL of packed red blood cells, 3000 mL of crystalloid solution, 1800 mL of fresh frozen plasma, and 650 mL of platelets. He underwent an immediate exploratory laparotomy during which a right hepatic lobecetomy and cholecystectomy were performed. His total blood loss was >3 liters. A T-tube was placed in the common bile duct, and he was returned to the pediatric intensive care unit. His postoperative course was initially unremarkable with discharge to home 11 days later after T-tube removal.

One week after discharge, the patient was readmitted complaining of abdominal pain and fever. An ultrasound revealed fluid collection in the right upper quadrant of his abdomen. Laboratory values were significant for a white blood cell count of 21.3 thou/μL (nL: 6.0–17.0 thou/μL), platelets of 659 thou/μL (nL: 150–400 thou/μL), segmented neutrophils of 82% (nL: 30–55%), and lymphocytes of 14% (nL: 30–55%). He was started on intravenous fluids and antibiotics. His fever continued. A chest radiography revealed a right pleural effusion whose drainage slowly tapered during his hospital stay. Fourteen days after admission he had minimal abdominal pain, and he was discharged to home.

DISCUSSION

This is the first study of pediatric handlebar-related injuries in which detailed circumstance and clinical data were collected prospectively to delineate the mechanism of this injury in sufficient detail for redesign of handlebars. This study used effectively a surveillance system supplemented by on-site crash investigations to delineate the typical injury mechanism in which a child, who lost control of the bicycle, began to fall. During the fall, the front wheel rotated into a plane perpendicular to the child's body. The child then landed on the end of the handlebar resulting in serious truncal injuries. Additional handlebar impacts resulted from bicycle mechanical failure. In these cases the child fell and landed on an unpadded stemcrown or crossbar.

Serious bicyclist injury from handlebar impact occurs with a history of an apparently minor incident, usually a fall. A previous case-control study of nonsevere child bicyclist injuries similarly found that minor circumstances, including low bicycle speed and riding on a sidewalk, were associated with emergency department visits. However, an explanation for these findings was not provided.[34] In the present study's cohort of child bicyclists, 16% of serious injuries resulted from handlebar impact and none involved collision with a motor vehicle. This is in contrast to the remaining 84% of serious child bicyclist injuries that primarily involved bicycle-motor vehicle collisions.

The frequency of handlebar impact in producing serious injuries in child bicyclists was confirmed by a multi-institutional study of child bicyclist injuries reported to the National Pediatric Trauma Registry. Ten percent of the bicyclists enrolled in that study impacted the handlebars. In the National Pediatric Trauma Registry Study, none of the handlebar-related injured subjects sustained a head injury. Furthermore, among the nonhead-injured bicyclists, these handlebar impacts accounted for 22% of the reported injuries, thereby representing a significant source of injury. In agreement with the results of our study, none of these handlebar-related events involved a motor vehicle. (Baker SP, Fowler CJ, Winston FK, Li G, DiScala C. *Sequelae of Head Injury in Child Bicyclists; Phase II.* Submitted to: The George Snively Research Foundation. The Johns Hopkins University Center for Injury Research and Policy. October 1997).

Our results also appear relevant to the findings of Clarnette and Beasley[7] who found that serious handlebar-related injury involves low-velocity crashes and often results in abdominal injury that may not be symptomatic until several hours after the injury. Because abdominal injuries can be occult, they may be missed by the diagnosing physician and the need for a thorough trauma history is essential to maximize efficient care.[35] The case report presented in this study specifically highlights how handlebar injuries can become a missed or delayed diagnosis. Recognition of the mechanism of handlebar-related injuries might have aided the pediatrician in early diagnosis of a liver laceration. The evaluating physician should ask a series of questions regarding the bicycle crash in an effort to determine if the handlebar was involved in producing injury. If a handlebar were implicated in the injury causation, a follow-up history and physical eliciting signs and symptoms of shock should be pursued.

The case report of the 6-year-old child also brings attention to the use of the stunt bicycle in the home environment. Five of the bicycle crashes subjected to in-depth investigation involved stunt-like bicycles. The potential hazard of stunt bicycles in producing handlebar-related injuries is corroborated by the work of Sparnon et al in 1982[23] and Sparnon and Ford in 1986[16] in which stunt bicycles were implicated in scrotal injuries and intra-abdominal system injuries, respectively. These studies and the results of the current study elicit concerns about whether the home environment is appropriate for stunt bicycle use.

In addition to the type of bicycle, the size appropriateness of the bicycle for the child is important. Improper bicycle sizing may impede the child's handling of the bicycle, potentially predisposing the child to falling, and may expose more of the child's trunk to the handlebar. Although improper bicycle sizing was not apparent in this study among those cases subjected to in-depth crash investigation, the potential consequence of improperly sizing a bicycle for a young rider must be considered.

The importance of the trauma history has been demonstrated previously elsewhere. Trauma histories focusing on discordancies between injury mechanism and actual physical damage to the victim have been essential in the detection of child abuse[36,37] and domestic violence.[38] Similarly, trauma histories have identified the role of air bags in child occupant fatalities in low speed crashes.[25-27] The emergency department can provide essential information for injury prevention and treatment if a sufficiently detailed trauma history is obtained.

This study was limited to a single level one pediatric trauma center and included only children with serious injuries to be able to identify specific circumstances associated with these injuries. To obtain incidence and prevalence data regarding bicycle handlebar-related injuries, further study should include data from the community regarding children with no or minor injuries.[33,39] Additionally, the sample size of the study does not allow for subgroup analysis of specific handlebar designs and their role in producing bicyclists' injuries. Previous studies performed on handlebar type were limited to describing the presence of protective padding on the ends of the handlebars.[8] Further study incorporating a larger data set and expansion of parameters might permit the development of specific recommendations. Additionally, a larger study of the serious handlebar injuries should be conducted to determine whether manufacturers should be encouraged to produce bi-

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cycles with curved handlebars, especially for small and younger riders. Such a study could also be used to explore the benefit of design limitations, such as limitation of rotation of the front wheel.

Handlebar-related injuries could potentially be avoided by curving handlebar ends away from the rider and padding the handlebar ends. These handlebar redesigns are recommended for all bicycle types. Limitation of the front wheel rotation is also recommended, but it is recognized that restricting the free rotation of the front wheel might not be acceptable to some stunt bicycle competitors. Consequently, consideration should be given to limiting the use of stunt bicycles to controlled competition settings with experienced riders.

Clinicians can play an important role in the prevention and treatment of handlebar-related injuries. Through anticipatory guidance, clinicians can educate parents about choosing and maintaining their child's bicycle. This education might include: proper sizing of the bicycle to the child; appropriate type of bicycle for the child's age and skill level, maintenance of the bicycle to prevent mechanical failure; and maintenance of handlebar guards. If a child bicyclist is injured in a fall, clinicians should elicit a complete trauma history from EMS personnel, children, and witnesses. Identification of handlebar impact may be essential to identifying serious occult truncal injuries in child bicyclists.

ACKNOWLEDGMENTS

This work was funded by Agency of Health Care Policy and Research Grant 5 U01 HD32828 as part of the Emergency Medical Services for Children Program.

We thank The Children's Hospital of Philadelphia Trauma Service, Philadelphia Fire Rescue, Frances Bents and Robert Schaar at Dynamic Science, Inc, Elisa Moll, Craig Rineer, Harry Jenkins, and Esha Bhatia for their contributions to this research.

REFERENCES

1. Sacks JJ, Holmgreen P, Smith SM, Sosin DM. Bicycle-associated head injuries and deaths in the United States from 1984 through 1988. *JAMA*. 1991;266:3016–3018
2. Li G, Baker SP, Fowler C, Discala C. Factors related to the presence of head injury in bicycle-related pediatric trauma patients. *J Trauma*. 1991; 38:871–875
3. Sosin DM, Sacks JJ, Webb KW. Pediatric head injuries and deaths from bicycling, United States. *Pediatrics*. 1996;98:868–870
4. Sacks JJ, Kresnow M, Houston B, Russell J. Bicycle helmet use among American children. *Inj Prev*. 1996;2:258–262
5. Thompson RS, Rivara FP, Thompson DC. A case-control study of the effectiveness of bicycle safety helmets. *N Engl J Med*. 1989;320:1361–1367
6. Thompson DC, Rivara FP, Thompson RS. Effectiveness of bicycle safety helmets in preventing head injuries. *JAMA*. 1996;276:1968–1973
7. Clarnette TD, Beasley SW. Handlebar injuries in children: patterns and prevention. *Aust N Z J Surg*. 1997;67:338–339
8. Acton CHC, Thomas S, Clark R, Pitt RW, Nixon JW, Leditschke JF. Bicycle incidents in children—abdominal trauma and handlebars. *Med J Aust*. 1994;160:344–346
9. Arkovitz MS, Johnson N, Garcia VF. Pancreatic trauma in children: mechanisms of injury. *J Trauma*. 1997;42:49–53
10. Herbert RJ, Turner FW. Traumatic abdominal wall hernia in a 7-year-old child. *J Pediatr Surg*. 1973;8:975–976
11. Kubalak G. Handlebar hernia: case report and review of the literature. *J Trauma*. 1994;36:438–439
12. Mitchiner JC. Handlebar hernia: diagnosis by abdominal computer tomography. *Ann Emerg Med*. 1990;19:812–813
13. Dreyfuss DC, Flancbaum L, Krasna IH, Tell B, Trooskin SZ. Acute trans-rectus traumatic hernia. *J Trauma*. 1986;26:1134–1136
14. Fraser GC. Handlebar injury of the pancreas. Report of a case complicated by pseudocyst formation with spontaneous internal rupture. *J Pediatr Surg*. 1969;4:216–219
15. Bergqvist D, Hedlin H, Lindblad B, Matzsch T. Abdominal injuries in children: an analysis of 348 cases. *Injury*. 1985;16:217–220
16. Sparnon AL, Ford WD. Bicycle handlebar injuries in children. *J Pediatr Surg*. 1986;21:118–119
17. Lackgren G, Lorelius LE, Olsen L, Wassen C. Hemobilia in childhood. *J Pediatr Surg*. 1988;23:105–108
18. Roberts GR. Traumatic abdominal wall rupture. *Br J Surg*. 1964;51: 153–154
19. Tracy TF, Silen ML, Graham MA. Delayed rupture of the abdominal aorta in a child after a suspected handlebar injury. *J Trauma*. 1996;40: 119–120
20. Rohatgi M, Gupta DK. Isolated complete transection of common bile duct following blunt bicycle handlebar injury. *J Pediatr Surg*. 1987;22: 1029–1030
21. Stanton PE, Brown R, Rosenthal D, Clark M, Lamis PA. External iliac artery occlusion by bicycle handle injury. *J Cardiovasc Surg*. 1986;27: 728–730
22. Seddon JA. Handlebar injury. *Br Med J*. 1970;4:222
23. Sparnon T, Moretti K, Sach RP. BMX handlebar. A threat to manhood? *Med J Aust*. 1982;2:587–588
24. Boswell WC, Boyd CR, Schaffner D, Williams JS, Frantz E. Prevention of pediatric mortality from trauma: are current measures adequate? *South Med J*. 1996;89:218–220
25. Winston FK, Reed R. Airbags and children: results of a National Highway Traffic Safety Administration special investigation into actual crashes. In: 40th Staapp Car Crash Conference Proceedings. November 4–6, 1996; Albuquerque, NM. Society of Automotive Engineers, Inc; SAE 962438.27
26. Hollands CM, Winston FK, Stafford PW, Shochat SJ. Severe head injury caused by airbag deployment. *J Trauma*. 1996;41:920–922
27. Hollands CM, Winston FK, Stafford PW, Lau HT. Lethal airbag injury in an infant. *J Trauma*. 1996;12:201–202
28. Winston FK, Schwarz DF, Baker SP. Biomechanical epidemiology: a new approach to injury control research. *J Trauma*. 1996;40:820–824
29. Puckett CD, ed. *Educational Annotation of the International Classification of Diseases, 9th Clinical Modification*. 4th ed. Reno, NV: Channel Publishing Ltd; 1995
30. Association for the Advancement of Automotive Medicine. *The Abbreviated Injury Scale, 1990 Revision*. Des Plaines, IL: Association for the Advancement of Automotive Medicine; 1990
31. Baker SP, O'Neill B, Haddon W, Long WB. The Injury Severity Score: A method for describing patients with multiple injuries and evaluating emergency care. *J Trauma*. 1974;3:187–196
32. Tingvall C. Children in cars. Some aspects of the safety of children as car passengers in road traffic accidents. *Acta Paediatr Suppl*. 1987;339:1–35
33. Waller JA, Skelly JM, Davis JH. Trauma center-related biases in injury research. *J Trauma*. 1995;38:325–329
34. Senturia YD, Morehead T, LeBailly S, et al. Bicycle-riding circumstances and injuries in school-aged children. *Arch Pediatr Adolesc Med*. 1997;151: 485–489
35. Sung CK, Kim KH. Missed injuries in abdominal trauma. *J Trauma*. 1996;41:276–282
36. Kempe CH, Silverman FN, Steele BF, Droegemueller W, Silver HK. The battered-child syndrome. *JAMA*. 1962;181:17–24
37. Caffey J. Multiple fractures in the long bones of infants suffering from chronic subdural hematoma. *Am J Roentgenol*. 1946;56:163–173
38. Council on Scientific Affairs, American Medical Association. Physicians and domestic violence. *JAMA*. 1992;267:3190–3193
39. Waller JA. Methodologic issues in hospital-based injury research. *J Trauma*. 1988;28:1632–1636

PROTECTING THE CHILD'S ABDOMEN: A RETRACTABLE BICYCLE HANDLEBAR

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Running head: A retractable bicycle handlebar

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PROTECTING THE CHILD'S ABDOMEN: A RETRACTABLE BICYCLE HANDLEBAR

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ABSTRACT

A surveillance system in the Emergency Department of a Level 1 pediatric trauma center previously identified minor bicycle crashes as a cause of serious child abdominal injury. A discordancy exists between the apparently minor circumstances and serious injuries sustained by child bicyclists who impact bicycle handlebars. The objective of this work was to redesign the bicycle handlebar to reduce the forces transmitted to the child's abdomen during an impact with the handlebars.

A retractable handlebar consisting of a spring-mass-damper system was designed to retract and absorb the majority of energy at impact. Since the child remains in contact with the bar after impact, the retracting system also includes a mechanism to damp the outward motion of the handlebar. This prototype will reduce the forces at impact by approximately 50% in a collision similar to those discussed above.

A unique methodology of translating research findings into product design produced a novel handlebar that absorbs significant energy that otherwise would be transferred to the child's abdomen when impacting the handlebar.

Keywords: abdominal injury, product design, bicycle safety

INTRODUCTION

Impact with the handlebar in slow speed bicycling crashes has been identified as a mechanism of life threatening truncal injuries in children. A thirty-year period of study of children's abdominal injuries (348 cases) showed that the predominant cause (104 cases) of abdominal injury in children age 6-10 years was bicycle accidents (Bergqvist, et al, 1985). In a study at a pediatric trauma center from 1980-1994, the largest percentage (27%) of pancreatic injury in children was a direct result of bicycle handlebars (Arkovitz, et al., 1997). A recent report documented a fatal delayed rupture of the abdominal aorta due to impact with the bicycle handlebar. (Tracy, et al., 1996).

A multi-institutional study of child bicyclist injuries using the National Pediatric Trauma Registry as a data source revealed that ten percent of the bicyclists enrolled impacted the handlebars and that none of those that impacted the handlebars sustained a head injury. Furthermore, of all children without head injuries, 22% of the injuries were due to handlebar impact. (Baker et al, 1997)

In our previous work, a prospective surveillance system in the Emergency Department of a Level 1 pediatric trauma center was used to identify children with this injury pattern and specifics of the injury mechanism were delineated through accident reconstruction (Winston, et al., 1998) The most common scenario was as follows: the child was riding forward when he/she came into contact with an obstructing object (i.e. curb, bump, rock, etc.). Upon contacting the object, the forward motion of the bicycle was stopped and, in order to gain his/her balance, the child turned the handlebar perpendicular to his/her abdomen. The child's momentum carried him forward impacting the handlebar. Following the forward motion the child fell to the ground while still in contact with the handlebar. The distal end of the handlebar collided with the ground, forcing the proximal end of the bar into the child's abdomen causing serious life-threatening injuries to the liver, spleen, and pancreas. (Figure 1)

No effective countermeasures have been developed to prevent these debilitating injuries. The goal of this study was to use a unique methodology to translate our research findings of handlebar injuries into the design of a novel handlebar system. This system would be able to absorb energy and reduce the force transferred to the child's abdomen in bicycle handlebar collisions.

METHODS

The child's body mass, the mass of bicycle, and specific dimensions of the bicycles were abstracted from the accident reconstruction reports from our previous work discussed above (Winston et al, 1998). Impact forces from a typical crash were determined using the equations of physical motion.

Initially, the person (p) is riding the bicycle (b) at an initial velocity of v_{bi}. When the child is initially thrown from the seat into the handlebar, a second system is established where there is only the momentum of the person due to the complete stop of the bicycle. The velocity of the child's initial impact with the handlebar ($v_{impact1}$) is equal to the initial velocity of the bicycle (v_{bi}).

$$V_{impact1}=V_{bi} \qquad (1)$$

The subject and the bicycle then fall toward the ground where upon impact, a significant force is exerted by the handlebar upon the subject. The force associated with the handlebar is given by:

$$F_{handlebar} = F(h)\sin\theta \qquad (2)$$

where θ is the angle of accident impact, h is the height of the center of gravity of the of the combined person and bicycle masses and is estimated to be 1.0m. In addition, an associated force due to gravity exists. If we assume that there is an initial velocity at impact with the handlebar ($v_{impact1}$), the acceleration in the vertical direction can be solved after finding the velocity of impact with the ground ($v_{impact2}$). The energy equation associated with the second collision is:

$$\frac{1}{2} m_p v_{impact1}{}^2 + (m_b + m_p)gh = \frac{1}{2}(m_b + m_p)v_{impact2}^2 \quad (3)$$

Acceleration in the vertical direction can be calculated to be the following:

$$a = \frac{v_{impact2}^2}{2h} \quad (4)$$

where velocity at impact can be calculated from the energy equation above. Thus, in conclusion, the general force diagram leads to an equation given by the following:

$$F(h)\sin\theta - (m_b + m_p)g = \frac{(m_b + m_p)v_{impact2}^2}{2h} \quad (5)$$

Solving for F(h) yields the force associated with the accident. Multiple forces were calculated by varying initial bicycle speeds and the angle of accident impact, θ. The range of initial bicycle speeds was chosen based on the crash investigations. These calculated forces were compared to the known compressive tolerance of the pediatric liver and spleen which have been previously measured to be 2649 Newtons and 785 Newtons, respectively (Sturtz, 1980).

Using a spring-mass-damper system, a novel handlebar was designed that, under pressures similar to those experienced during a crash, would retract and absorb the majority of the energy at impact. In this design, the handlebar system would no longer be fixed upon collision. Since the child remains in contact with the bar, the retracting system cannot return to the original position with the same force rate that caused it to initially retract. The new bar would include a system to damp outward motion of the bar. In addition to the retracting mechanism, the surface area of the handlebar ends would be increased to help distribute forces on the body.

The mathematical system chosen to represent the new design was a spring mass damper system which can be described by the following equations:

$$(m_p + m_b)\frac{d^2x}{dt^2} + c\frac{dx}{dt} + kx = F(t) \qquad (6)$$

In the equation above, all variables (mass (m), acceleration (d^2x/dt^2), maximum compression (x), force at impact (F(t)), and velocity at impact (dx/dt)) are known except for k and c, the spring constant and viscous damping coefficient, respectively. Therefore, iterating values for k will yield corresponding values for c.

RESULTS AND DESIGN

Six cases in which a child experienced serious abdominal injuries due to handlebar impact were analyzed (Table 1). Table 2 represents calculations of the force at impact (solution to Equation 5) from an average initial bicycle speed of 6.4 kph. The force due to the initial impact of the child with the handlebar was calculated to be approximately 300 Newtons. Forces due to impact with the ground ranged from approximately 1200-7000 Newtons, with an average of 2355 Newtons, (6.4 kph initial bicycle speed) depending upon the angle at impact. These calculations showed that the initial force of contact immediately following the drastic change in bicycle velocity is much less than the final impact with the ground. Thus the impact with the ground is the causal factor, not the initial contact force.

The average impact force of 2355 Newtons is considerably larger that the 785 Newtons required to rupture the spleen. Furthermore, the 2355 Newton value is comparable to the force at which the liver was found to rupture, 2649 Newtons. Speeds exceeding 6.4 kph initial bicycle velocity (i.e. 8.0-12.9 kph for this study) have larger average force values than the liver rupture force tolerance.

A standard industrial spring and damping grease (TAI Lubricants, Hockessin, Delaware) were chosen to provide the resistance and damping for the new prototype handlebar design, respectively. The damping grease (NyoGel 774VL) had a dynamic viscosity of 106 N-s/m^2. This dynamic viscosity correlated with a spring constant of 1752 N/m or 10 lbs/in. To aid in distributing the forces associated with impact, a protective cushion made of rubber-coated foam was added to the end of the bar, which increased the surface area at the end. The prototype is pictured below (Figure 2).

The spring is fixed at both ends and "rides" along a shaft which supports the spring. The shaft provides the safer handlebar system with dynamic stability. Upon an impact force from the handlebar end, the handlebar would compress depending upon the magnitude of the impact force, and then release at a slower rate due to the damping effect of the grease. For a 6.4 kph initial bicycle speed, the force at impact would reduce by approximately half from 2355 Newtons to 1177 Newtons. Photos of the actual machined handlebar are shown in Figure 3.

DISCUSSION

A unique methodology was employed that translated research findings into product design: the mechanism of injury due to handlebar impact was delineated and a new handlebar design to mitigate these injuries was developed. This design absorbs significant energy that otherwise would be transferred to the child's abdomen when impacting the handlebar.

The prototype described in this report is a concept stage design only. Further work would need to be done to completely characterize its performance and optimize the design for manufacturing and production. For this design, the length of the spring was based on a set distance determined from the bicycles used in the actual cases. In manufacturing the system, there are several parameters that can be varied. Changing the compression distance, and consequently the length of the spring, changes the spring constant. An optimization of these parameters allows for the development of the least expensive, most effective unit. Additional work needs to be done to assess the viability of a stiff spring (higher spring constant) versus a yielding spring (lower spring constant with more flexibility) with smaller and larger compression distances respectively. In addition, the performance of the handlebar must be assessed for all angles of impact.

Although this design significantly reduced the forces transmitted to the abdomen (by half) in these types of crashes, the maximum force in the redesigned handlebar was calculated to be above the known tolerance of the spleen (approximately 800 Newtons). It is important to note that this tolerance level was determined from a single test in a 10-year-old child and as a result, may not be an exact value. This data, however, represents the only information available and as a result, is the basis for the handlebar design. In the next generation design, the forces should be further limited to a safety factor of at least 2 below the spleen tolerance, i.e. the maximum force should be limited to 400 Newtons. This could be achieved simply by using a different combination of spring and damping grease.

In designing a device that is to be implemented on all bicycles, it is also important to consider price and practicality. The actual shape of the handlebar can only be changed such that the functional purpose is not altered. If the children cannot maneuver with the same ease, then they are more likely to have accidents. In addition, the device must be aesthetically appealing to children in the target age group. During investigation of the crashes described herein, it was determined that children often remove safety features on bicycles to increase the maneuverability or aesthetics. If they feel that the handlebar makes the bike look strange or uncomfortable, they will be less likely to purchase it. Prior to determining a final handlebar design, a focus group of children should be conducted, testing the aesthetics of possible handlebar systems. In particular, the children's input should be considered in developing the mold for the rubberized foam padding that would be placed on the handlebar ends.

CONCLUSIONS

A unique methodology of translating research findings into product design produced a retractable handlebar consisting of a spring-mass-damper system that, under pressures similar to those experienced during a crash, retracts and absorbs the majority of energy transferred to a child's abdomen at impact. This prototype was designed to reduce the forces at impact by approximately 50% in a collision similar to those that have previously caused injury. This design will be instrumental in reducing the severity of abdominal injuries experienced by young cyclists.

ACKNOWLEDGEMENTS

This work was funded by Agency for Health Care Quality (formerly known as Agency for Healthcare Policy and Research) Grant number 5 U01 HD32828 as part of the Emergency Medical Services for Children Program. The authors would like to acknowledge Dynamic

Science Inc. and the United States Consumer Product Safety Commission who performed the crash investigations, Rajiv Menon, PhD, for his advice during the prototype design, and Joe Pilli for his advice and assistance in the machining of the prototype.

REFERENCES

Arkovitz MS, Johnson N, and Garcia VF. 1997. Pancreatic Trauma in Children: Mechanisms of Injury. J Trauma. 42, 49-53

Baker SP, Fowler CJ, Winston FK, Li G, DiScala C. 1997. Sequelae of head injury in child bicyclists: Phase II. Submitted to: The George Snively Research Foundation by The Johns Hopkins University Center for Injury Research and Policy.

Bergqvist D, Hedelin H, Lindblad B, and Matzsch T. 1985. Abdominal Injuries in Children: an analysis of 348 cases. Injury. 16, 217-220.

Sturtz, G. 1980. Biomechanical Data of Children. Proceedings of the 24th Stapp Car Crash Conference. Troy, Michigan: Society of Automotive Engineers.

Tracy TF, Silen ML, and Graham MA. 1996. Delayed Rupture of the Abdominal Aorta in a Child after a Suspected Handlebar Injury. J Trauma. 40, 119-120.

Winston FK, Shaw K, Kreshak AA, Schwarz DF, Gallagher PR, and Cnaan A. 1998. Hidden Spears: Handlebars as Injury Hazards to Children. Pediatrics 102, 596-601.

Table 1-Case Summaries

Case #	Child age (yrs)	Child mass (kg)	Handlebar turn radius(deg)	Bicycle Weight (kg)	Injury
1	14	50.3	90	12.3	Severed kidney, bruised pancreas
2	11	49.8	360	12.9	Splenic laceration
3	7	31.7	360	14.7	Splenic laceration
4	8	27.0	90<r<180	12.9	Liver laceration
5	11	43.0	360	10.9	Splenic laceration
6	6	25.0	360	Unknown	Liver laceration

Table 2 - Force Calculations for 6.4 kph (1.8 m/s) Initial Bicycle Speed

m_b (kg)	m_p (kg)	v_b (m/s)	$v_{impact2}$ (m/s)	θ (degrees)	Force at impact (N)
12.6	44.1	1.8	4.7	10	6811
12.6	44.1	1.8	4.7	20	3458
12.6	44.1	1.8	4.7	30	2366
12.6	44.1	1.8	4.7	40	1840
12.6	44.1	1.8	4.7	50	1544
12.6	44.1	1.8	4.7	60	1366
12.6	44.1	1.8	4.7	70	1259
12.6	44.1	1.8	4.7	80	1201
12.6	44.1	1.8	4.7	90	1183

Figure 1

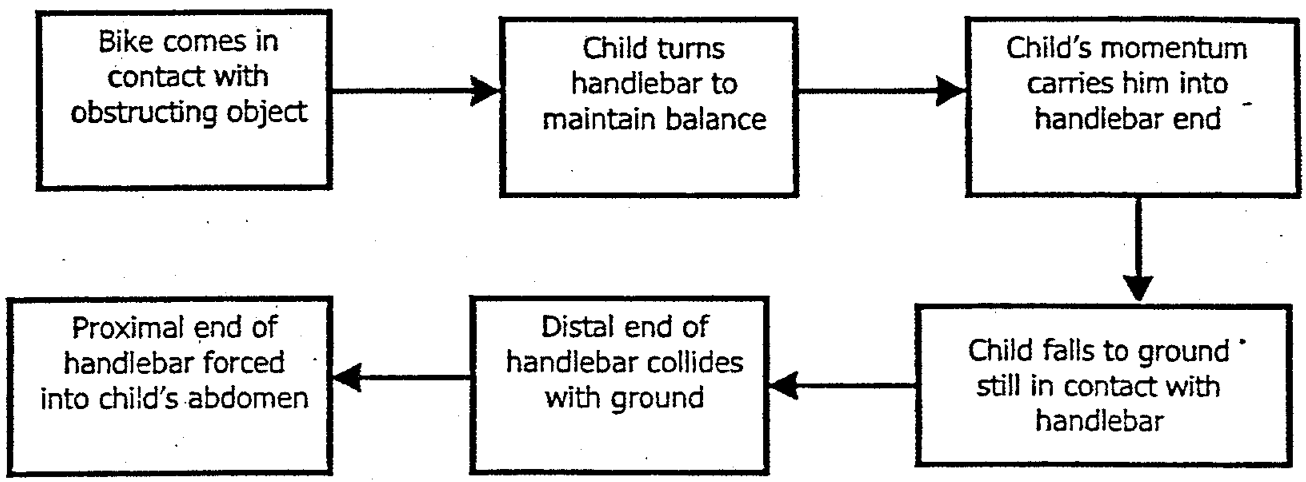
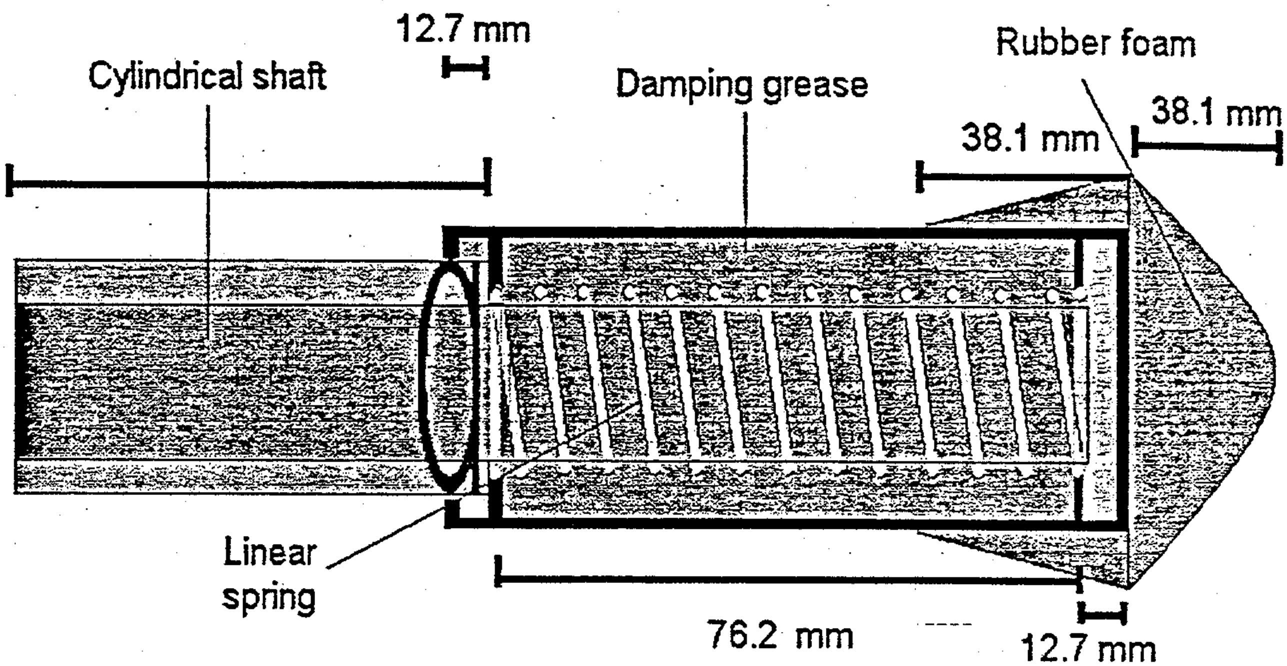

Bike comes in contact with obstructing object
Child turns handlebar to maintain balance
Child's momentum carries him into handlebar end
Child falls to ground still in contact with handlebar
Distal end of handlebar collides with ground
Proximal end of handlebar forced into child's abdomen

Figure 2



12.7 mm
Cylindrical shaft
Damping grease
Rubber foam
38.1 mm
38.1 mm
Linear spring
76.2 mm
12.7 mm

Figure 3

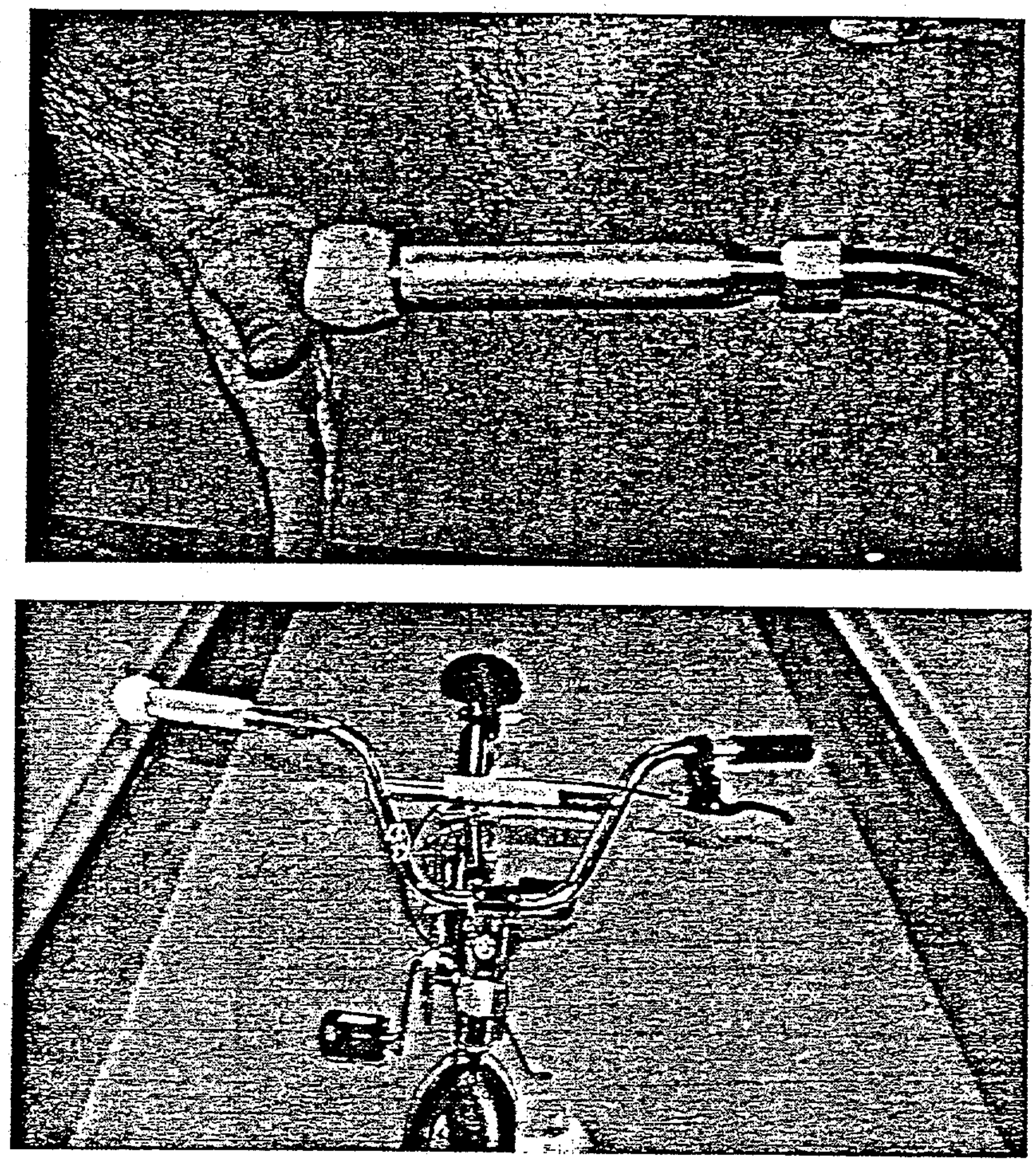


Figure captions

Figure 1 – Schematic of injury event unfolding.

Figure 2 - Theoretical prototype of redesigned handlebar. The design consists of a linear spring on a cylindrical shaft surrounded by damping grease. Upon impact, the spring would compress and then release at a slower rate due to the damping effect of the grease.

Figure 3 – Actual photos of redesigned handlebar.

TAB B

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

17 APR 2003

TO : Barbara Jacobson, HS, and Debra Sweet, EHHA

THROUGH: Warren J. Prunella, AED, EC *WJP*

FROM : Elizabeth W. Leland, EC *EWL*

SUBJECT : Petition HP 01-1: Bicycle Handlebar Performance Standard

Enclosed with this memorandum is a report that provides product and market information about bicycle handlebars. The material in the report is for use in consideration of Petition HP 01-1.

Enclosure

BICYCLE HANDLEBARS

PRODUCT AND MARKET INFORMATION

Elizabeth W. Leland
Directorate for Economic Analysis
September 2002

Bicycle Handlebars
Product and Market Information

Table of Contents

BICYCLE HANDLEBARS
PRODUCT AND MARKET INFORMATION

I. Introduction

In December 2000, the U.S. Consumer Product Safety Commission (CPSC) received correspondence regarding bicycle handlebars from Flaura Koplin Winston, M.D., Ph.D., Director, TraumaLink, The Interdisciplinary Pediatric Injury Control Research Center, The Children's Hospital of Philadelphia. Dr. Winston requested that the Commission issue a rule to minimize abdominal injuries from the impact of bicycle handlebars when a cyclist falls from his or her bicycle. In addition, Dr. Winston provided information about the technical feasibility of designing safer handlebars. The Commission docketed the correspondence as a petition under provisions of the Federal Hazardous Substances Act (FHSA).

This report provides product and market information for use in consideration of the petition. A description of the types of handlebars that are available on the market is included, as is a description of the manufacturing processes used to make handlebars. In addition, some structural and economic aspects of the market for handlebars are discussed, including the segmentation of the retail market, the relationship of the handlebar industry to the bicycle industry, domestic distribution channels for bicycles and components, manufacturers, production volume, sales, retail prices, and bicycle use. The information in this report is based on books about bicycling, trade press, and various Web sites.

II. Product Description

A. Product Definition: What is a Handlebar? What is its Function?

A bicycle handlebar is classified by the industry as a "bicycle component"; it is one of several items that are attached to a bicycle frame to make it a "complete bicycle" or a bicycle that is ready to ride. Other bicycle components include handlebar grips, bar ends, gears, stems, forks, brakes, shifters, saddles, and pedals.

The frame of a bicycle consists of the head tube, top tube, seat tube, down tube, forks, seat stays, chain stays, and bottom bracket (see Appendix A). The bicycle handlebar is attached to the frame of a bicycle by the handlebar stem and is one of three points of rider contact with the bicycle, the other two being the saddle and the pedals.[1] The handlebar is used by the rider to help control the steering and balancing of the bicycle. Other bicycle components, such as grips, bar ends, brake levers, and shifters sometimes are attached to handlebars.

B. Handlebar Configurations

1. Handlebars in Common Use

Handlebars are made in several configurations. The common configurations currently on the market are referred to as "flat", "riser", "drop", and "aero" (see Appendix B, Figure 1). Flat bars generally are used on mountain, hybrid, folding, and electric-assisted bicycles.[2,3] They are sometimes known as "straight" bars. They do not curve upwards, but can curve back very slightly towards the rider. Riders often use "bar ends" to increase the number of hand positions that are available with flat bars; "bar ends" are metal extensions that can be bolted onto the ends of handlebars in a vertical or nearly vertical position. A recent development in the design and marketing of the flat bar is the "Women Specific Design" (WSD) handlebar; this is a flat bar that is smaller and has a more compact geometry than typical flat bars. It is designed to fit the hand and wrist sizes of women.[4]

"Riser " bars (sometimes called "upswept", "upright", or "cruiser" bars) are used primarily on cruiser, dirt, children's, tandem, folding, and electric-assisted bicycles.[5] They are designed with an upward sweeping center section that allows the rider to sit in a more upright and stable position. One variation of the riser bar is the "high-rise" handlebar that is used on some children's and dirt bicycles and children's tricycles. Some models of riser handlebars incorporate a reinforcing crossbar and are sometimes referred to as "system" bars. Unlike other handlebars that generally are made from a single piece of tubing, these bars often are made of several tubes (sometimes as many as 4 or 6) joined together to form the riser/crossbar shape.

"Drop" bars generally are found on road, tandem, folding, and electric-assisted bicycles. Sometimes known as "road" bars, they curve downwards and then backwards. From a side view, drop bars have a profile shaped like the letter "C".[6] Some drop bars have a continuously curved "C" while others, known as "anatomic" drop bars, have one or more straight areas interspersed with the curved areas.[7] Drop handlebars provide "a variety of hand positions and a more aerodynamic posture for the rider."[8] The variety of available hand positions - near the stem, on the upper middle part of the bar, on the lower middle portion of the bar, and on the drops or very bottom of the bar - can be used to increase the rider's comfort. Similarly, the straight sections of anatomic drop bars can be more comfortable for some riders to hold onto than the curved sections. Drop handlebars usually have grooves along the upper section to hold brake and shift cables.[9]

"Aero" or "triathlon" bars first appeared in the mid-1980s. They are designed with an elbow/arm rest and a grip that places both hands almost together. Some models of aero bars are independent and clamp onto the top of other types of bicycle handlebars, while other models that are designed for use with a specific bicycle stem are purchased and used as an integrated stem/aero bar unit. With aero bars, the rider can increase speed by decreasing wind resistance. However, steering a bicycle can be more difficult with aero bars, because the rider reportedly does not have as much control of the bicycle.[10] Similarly, it can be difficult to maneuver the bike quickly if the rider needs to avoid running into an obstacle.[11] Aero bars originated as racing equipment, but one writer mentions that they are now becoming popular with riders of touring bicycles because of the relief that they can provide for hands and wrists.[12]

2. Other Types of Handlebars

Another type of handlebar that is available, but not in common use, is the moustache handlebar (see Appendix B, Figure 2). The moustache handlebar is shaped like the letter

"M" (from the rider's view) and has a vertical drop.[13] A type of handlebar that once was popular on mountain bicycles is the bull moose handlebar. The handlebar stem splits in two and attaches to the handlebar at two points, rather than at one common point.[14] Although the bull moose handlebar is not commonly used, at least one Web site advertises its capability for providing a custom-made bull moose handlebar.[15] A recumbent handlebar is a very small handlebar that is used on a recumbent bicycle. It is placed either under the seat or in front of the bicyclist, at shoulder height.

C. Handlebar Construction[16]

1. Materials

A. Criteria for Making Handlebars

The criteria manufacturers consider when making bicycle components include impact and fatigue strength, weight limits, and affordability. To function well, handlebars need to be strong enough to withstand reasonable loads, yet be light and durable. They need to be able to bend under unreasonable stresses and to bear accumulated loads, stresses, and impacts.[17] Manufacturers also consider the costs of the materials they use and the impact of those costs on market competitiveness.

Component designers and manufacturers consider how various materials meet these criteria and explore ways to take advantage of the strengths and compensate for the weaknesses of particular materials. As a result, there are a wide variety of handlebars on the market – not only in terms of configuration, but also in terms of material of construction.

B. Historical Use of Various Materials

Bicycle handlebars (and frames) historically have been made of various materials, including wood and steel. In the 19th century, solid steel bars were used for bicycle handlebars.[18] Today, frames and handlebars are shaped from hollow tubes made of various metals and composites. Breakthroughs in materials and a growing market for high-technology cycling products accelerated the evolution of bicycle frames and components in the 1980's.[19] Since the 1980's, there has been an evolution in the types of materials used to make bicycle components, particularly in the development and use of composites. Currently, the metals used to make handlebars include steel, chromoly (a blend of steel, molybdenum, and chromium), aluminum, titanium, and more recently, magnesium; the composites include Kevlar fiber, carbon fiber, and other high-technology materials. Some of the alloys and composites are proprietary to the companies that develop them.

C. Metals

Steel, an alloy of iron and carbon, is the most traditional material for bicycle handlebars, either alone or when combined with other materials. Many types of steel tubing are available, and it is easy to shape. It is durable, relatively inexpensive, can be easily repaired, can bend a great deal before it fails (a high tensile strength), and absorbs vibrations well. However, it rusts and is heavy compared to other materials. Steel alloyed with chromium and molybdenum is used for some bicycle components, including handlebars; the alloy is known as "chromoly", "CrMo steel", or 4130 steel.

Aluminum bicycles have been in existence since the late 1800's, but only recently have aluminum bicycles and components become competitive with steel. Aluminum in general is relatively inexpensive, lightweight (about one-third the weight of steel), does not rust, and is shock absorbing. It can be mixed with copper, manganese, silicon, magnesium, and zinc. Aluminum alloys are used for many bicycle parts, including handlebars. However, aluminum alloys are not as strong or as easily repaired as steel; "6061 aluminum", for example, is only about 80 percent as strong as "4130 chromoly steel". In addition, aluminum is not as resilient as steel and does not have as high a tensile strength; the more it bends, the quicker it reaches its end of life. Manufacturers can compensate for this by using larger diameter tubing that limits the amount of flexing that occurs during bicycle riding. Aluminum alloys differ from one another in tensile strength, corrosion resistance, welding compatibility, and ductility, and manufacturers take into account their specific products and markets when choosing a particular aluminum alloy. Although not as shock-absorbing as steel, increases in the number of alloys, as well as improvements in construction techniques, reportedly have led to an increase in the shock absorbency of aluminum frames and components.

Titanium (sometimes referred to in marketing literature as "Ti") is lightweight, has high shock-absorbing qualities, is resilient like steel, is corrosion-resistant, and has a fatigue life up to 5 times that of steel or aluminum. It does not need to be painted and continues to maintain its original appearance over a long period of time. However, titanium components are not as easily repaired as components made of other materials; in addition, because titanium is relatively hard to obtain and requires special metalworking tools and controlled environmental conditions, it is costly to produce. One writer reports that titanium tubing can cost up to 15 times more than steel.[20]

Magnesium is extremely lightweight (reportedly a magnesium bicycle frame that weighs only 2.8 pounds has been made), is recyclable, and is gaining acceptance in the manufacture of components. However, it currently is about 40 times as costly as aluminum, and this cost differential is expected to hinder extensive use.[21]

D. Composites

A composite is a combination of individual materials; the composite has properties greater than what each material would have if used individually. The technology of composites was developed in the aerospace industry, and, as early as the 1970's, experiments using carbon fiber composites were conducted in the cycling industry. In 1986, a bicycle manufacturer built a molded one-unit bicycle frame (known in the industry as a "monocoque" frame); this led to greater use of composites in frame and component manufacture.[22]

Composites generally are materials comprised of "particles, short or long fibers that are dispersed in a matrix" material such as an epoxy resin or an adhesive.[23] Composites used for bicycle frames and handlebars usually have continuous fibers embedded in epoxy. Unlike metals, which must be formed during manufacture into a particular geometrical shape and are equally strong and stiff in all directions, composites can be shaped in many ways and their strength and stiffness can be directed into the places of the composite where they are most needed. Thus, desired properties can be incorporated into the manufacture of composite frames and components.

Composites are very lightweight (some are only one-fourth the weight of steel) and durable, absorb vibrations, are resistant to corrosion, and have a better fatigue life than metals. However, while able to be shaped in countless ways, composites also are stiff once they are heated into a final shape; after shaping, they can not be as easily bent as steel, so changes cannot be made as easily after shaping as with steel. Because production methods require specialized technical expertise, they are relatively costly, as are the carbon fibers and resins themselves. Composite bicycle components also are costly relative to components made of metals. Thus, carbon fiber handlebars generally are currently available only at the high-dollar-end of the market. However, increasing demand is resulting in prices of composites moving downward towards increasingly affordable levels.

2. Manufacturing Processes Used to Make Handlebars

A. Manufacture of Tubing

As noted above, handlebars are formed from hollow tubing of various materials. Historically, the hollow tubes used in bicycle frames and handlebars were cylindrical throughout; today, tubing for bicycle frames and components can be round, elliptical, rectangular, or triangular and may not be the same diameter throughout the length of the tube.[24] For tubing manufacturers, "the challenge lies in creating tubes that offer an appropriately stiff ride horizontally, retaining vertical compliance (a forgiving ride), while at the same time withstanding the rigors and abuse of everyday riding, racing, and transporting the bicycle."[25]

In general, tubes of steel or steel alloys can be seamed or seamless, and both types are used to make handlebars. Seamless tubing is made by rolling a hot billet or rectangular piece of steel between two plates, causing a cavity to form down its center. The billet is rolled around a mandrel to increase the inside diameter. This process produces a thick walled tube, which is either cross-sectional or butted: cross-sectional tubes are the same diameter throughout and butted tubes are thickened at the ends or at joints to better handle stress and thinned out in the center to reduce weight. Seamed tubing is made by rolling a flat continuous strip of metal into a tubular shape, then joining the edges of the tube by welding. In general, seamed tubes are the same diameter throughout the length of the tube. Both seamless and seamed tubing can be hot-rolled to reduce the outside diameter and decrease wall thickness, then cold-drawn (pulled at room temperature through a die or hole of smaller size) to increase strength and to provide a better surface finish. Aluminum and aluminum alloy tubing generally is made by seamless drawing. Some aluminum alloys are heat-treated (a process in which metals are heated to a specific temperature and then cooled under controlled conditions) to increase strength. Titanium tubes are hard and time-consuming to make, primarily because titanium is a hard metal. Even with machines, it reportedly is difficult to manipulate. Titanium alloy tubes generally are seamless and cold-drawn.

Tubes made of composites are formed in several ways, and the manufacturing process can affect the material properties of composites. The filament winding process occurs when continuous fibers are passed through a resin bath and then wound over a rotating or stationary mandrel. Fibers are wound on the mandrel in a pattern of successive layers at a constant or varying angle. The mandrel is withdrawn after wrapping. Other processes include roll wrapping, braiding, and pultrusion, in which fibers are pulled through a heated mold that melts the matrix material. Some tubes are made by a combination of these methods. Each manufacturer can determine the number and direction of the layers that are formed so that the desired combination of strength, weight, and stiffness can be created. The size and shape of each tube can be matched to predicted loads of pedaling and road shock. Rigidity can be varied, and strength can be distributed where needed.

B. Cutting, Bending, and Finishing the Tube

After a metal tube is made, it is cut to the size desired. Metal tubes can be cut with a drill press (punching), miters, or computer-controlled laser machinery. After cutting, metal tubes are formed into handlebars by a bending process. The tube is held in place and pressed against a form until the desired shape is achieved. To prevent the tube from buckling or folding, a mandrel is placed inside the tube, and the mandrel supports the tube wall so that it is not crushed at the place where it bends. Composite tubes are made into the desired shape and size during the tube manufacturing process.

After metal tubes are cut and bent, they are hardened, and tested. They can be filed, sanded, polished, anodized, powder-coated, and/or painted with protective and decorative finishes. Sometimes tubes are shot-peened, or subjected to bombardment with small spherical pieces of material called shot. Shot peening increases the product life by increasing resistance to various types of metal fatigue.[26] Composite tubes are protected with urethane enamel coatings, or sometimes an aluminum core wrapped with carbon fiber and Kevlar is placed inside the tube to protect against severe damage. Some manufacturers use an outer "sacrificial layer" to protect the composite tube.

C. Joining Processes

The greatest points of stress on a bicycle frame or components are the joints - the places where two pieces are joined together. A joining process would be needed, for example, on a bicycle with a riser handlebar with a crossbar. The traditional method of joining two tubes or two pieces of material is a lug or a reinforcing sleeve that strengthens the joint. The lugs and tubes are joined together by soldering or by brazing, so that the space between the tube and the lug fills up with molten brass or a silver alloy. Welding, which does not require the use of lugs, also can be used as a joining process. Aluminum and carbon fiber bicycles sometimes use adhesive bonding, a more expensive technology that is used on upper-end-of-the-market and custom bicycles. In addition, the use of molds and the ability to make varying shapes and sizes of composite tubing can be used to eliminate the need for a joining process.

3. Handlebar Characteristics

When sold, handlebars often are described in terms of one or more of the following characteristics: reach, rise, drop, bend, and sweep. "Reach" is the distance from the stem to the handlebars. "Rise" is a characteristic of the riser bar and is the vertical distance from the low point of the bar (the middle) and the high points of the bar (typically the grip area). "Drop" is a characteristic of a drop handlebar and is the distance from the top of the handlebar to its lowest point. "Bend" is the angle at which a straight or flat handlebar is bent; flat handlebars sometimes have a minimal to small bend. "Upward sweep" is the angle at which a riser handlebar bends upward, while "backward sweep" is the angle at which a handlebar curves backward. These characteristics are important to the comfort of the rider and the fit of the bicycle to the rider.

4. Product Development

A. General

There is ongoing development in the design and manufacture of handlebars. In the 2000 edition of the National Bicycle Dealers Association *StatPak*, it is stated that "since the 1970's boom, no part of the bicycle has remained unchanged, with fundamental improvements in design and materials being the norm throughout the industry".[27] Not only are various materials being tested for use as bicycle components, but also new variations on handlebar designs are being developed and explored. Although current design and manufacturing handlebar criteria are the traditional criteria of strength, low weight, and affordability, the ways in which those criteria can be met are undergoing constant exploration.

B. New Products

With respect to handlebars, a new type of headset (the bearing assembly that connects the front fork to the frame and allows the fork to move) with a safety device recently came onto the market. The safety device is incorporated directly into the headset and internally restrains the steering angle of the handlebars to 130 degrees (65 degrees to each side from the straight wheel position). This in turn restricts the front wheel and handlebars to a forward direction. The manufacturer indicates that this device will prevent the handlebars and front wheel from turning beyond a forward direction, thus eliminating the possibility that the rider will be thrown into the handlebars.[28]

The petitioner submitted information about a prototype retractable handlebar design with a spring-mass-damper system that, under pressures said to be similar to those experienced during a crash, retracts and absorbs the majority of energy transferred to a child's abdomen at impact. This prototype design reportedly is patent pending.[29]

Another relatively new handlebar on the market is the SmartBar™. This handlebar is designed to hold headlights, a computer to measure speed, distance, and time, mirrors, and a compass.[30]

A folding handlebar recently was developed for a folding bicycle. It is a standard handlebar that fits standard stems and brake levers; the only difference is that it can fold up along with the bicycle and be carried in a pack or bag.[31]

III. Bicycles and Bicycle Components: Market Information

A. Structural Characteristics

1. The Market for Bicycles and Components

Bicycle manufacturers are firms that manufacture, assemble, or source the production of bicycles for sale to the public. Bicycle components manufacturers, in contrast, manufacture parts or components that are used in the assembly of bicycles by original equipment manufacturers (OEM's) or can be purchased directly by consumers. Thus, the market for handlebars has two aspects. The first is the original equipment market, i.e., the market for new handlebars that are placed on new frames, so that a new bicycle can be sold as a complete bicycle. Bicycle manufacturers are the primary buyers in the original equipment market.

The second aspect is the aftermarket, i.e., the market consisting of cyclists who want to change, upgrade, or repair the handlebars on their bicycles. Bicycle owners sometimes want to change handlebar height, width, or style; this could occur, for example, if a rider purchased a used bicycle and wanted a handlebar made of a lighter-weight material or wanted to convert a drop handlebar to an upright or riser handlebar. In addition, "hard-core mountain bicycling has increased the demand for parts to upgrade technologies or to replace broken parts. Mountain bike racing, with the pounding of downhill areas and muddy terrains, can be hard on parts, causing more frequent replacements."[32]

According to the U.S. Department of Commerce, parts such as fork suspensions, brake pads, chains, and tires are the components most likely to be replaced; handlebars do not appear on this list.[33] At the same time, one writer mentioned that handlebars are generally replaced on the average about every two years.[34] This is probably more likely to occur on a bicycle that is used often for heavy-duty riding, such as a mountain bicycle, than on a street or casual rider's bicycle and on a more expensive bicycle than on an entry-level bicycle, such as a child's first bicycle.

2. The Segmented Retail Market

There are three main outlets by which bicycles are sold in the United States: mass merchandise stores, specialty or independent business dealers (IBD's), and full-line sporting goods stores. Manufacturers generally distribute their bicycles through only one of these types of outlets. In mid-2001, one manufacturer was known to be supplying both the mass merchant and the IBD channels. However, industry analysts expect that price competition, as well as the IBD's desire to keep their product separate from the mass merchandise product, likely will be obstacles to widespread crossover in the channels of distribution.

Mass merchandise stores, which include department and discount stores such as Target, Wal-Mart, and Toys "R" Us, sell mostly less expensive bicycles.[35] Most of the bicycles are imported, primarily from China, and sold in a box, ready for assembly by either the consumer or the retailer. Components such as handlebars are *not* sold in mass-merchandise stores.

IBD's generally sell higher-quality and more expensive merchandise. Service is a major selling feature. Some merchandise available in these specialty shops is imported, while other merchandise is produced in the United States. Most U. S.- made aftermarket bicycle components are sold by IBD's only.[36] There are about 6,000 IBD's that sell bicycles and components, such as handlebars, in the U.S. As of June 2001, nearly 20 percent were located on the Pacific coast (including Hawaii and Alaska), while nearly 16 percent were located in East North Central states. Fourteen percent were located in the South Atlantic states and another fourteen percent in the Middle Atlantic states.[37] Most IBD's are single location businesses; only about 13 percent have shops in two or more locations.[38] About twenty-five percent of these stores concentrate on the high-end of the IBD market and sometimes are known as "pro shops". Handlebars sold in the after-market are sold almost exclusively by IBD's.

A third channel of distribution for bicycles is the full-line sporting goods stores. This channel includes about 30 national and regional retailers such as The Sports Authority, Champs Sports, and Big 5 Sporting Goods. These stores differ from mass merchandise stores in that they sometimes have a service department.[39] Like mass merchandise stores, however, sporting goods stores do not sell handlebars for the aftermarket.

Although not a significant channel of distribution for complete bicycles or components, there are several Web sites through which consumers can purchase components, including handlebars.

B. Economic Characteristics

1.Manufacturers

The CPSC Directorate for Economic Analysis (EC) staff has identified about 80 domestic manufacturers of handlebars. As described above, the manufacture of handlebars involves metal fabrication or the manufacture of composites. Some companies that make handlebars are metal fabricators or composite manufacturers that produce a variety of products. Their primary product line consists of fabricated metals or composites, *not* necessarily bicycle components.

Tubing manufacturers that produce handlebars usually enter the bicycle components market in one of two ways. Some produce, bend, and finish the tubing into a bicycle handlebar and market it as a product under their company name. Others sell the raw tubing to bicycle components manufacturers for shaping and finishing.

The close link between metal fabrication/composite manufacturing processes and the manufacture of handlebars was exemplified recently when a contract machine shop became a bicycle components manufacturer. Prior to producing handlebars, the company made aerospace components, cell phone parts and camera assemblies for the medical industry. According to a report in the trade press, about four existing companies have begun to fabricate bicycle components in recent years. According to one company representative, "When you have an established background manufacturing high-end, precision products, the move to bicycle components is fairly easy."[40]

2. Production Volume and Sales

According to the U.S. Department of Commerce, U.S. production of bicycle components (all components, not only handlebars) remains strong, although most production appears to be for overseas companies. U.S. exports of bicycle components account for a large proportion of U.S. production and do not appear to have been affected by the strong dollar.[41] This may partly be a result of U.S. manufacturers being known for their use of high-technology materials and innovative component technologies.[42]

Information about production volume of domestically produced handlebars is not readily available. U.S. Department of Commerce data is subsumed within the general category "components". However, data on sales of new bicycles provide a lower-bound estimate of bicycle handlebars sold in the U.S.

Sales of bicycles, as measured by supplier sales to distribution channels, reached a record high in 2000 of nearly 20.6 million units. This was an increase of 18 percent from 1999 sales volumes. Nearly all (98 percent) of these bicycles were imported.[43]

EC staff used trade press and other published information about sales of bicycles to estimate the percent of sales accounted for by various types of bicycles and handlebars. These estimates are shown in Table 2.

Table 2
Types of Bicycles Sold in 2000[44]
As a Percent of Total Sales and by Type of Handlebar

Type(s) of Bicycle	Percent of Total Bicycle Sales	Type of Handlebar
Mountain/ Hybrid[45]	46.1	Primarily flat
BMX/Juvenile	43.8	Primarily high-riser
Road	1.1	Drop
Cruiser	0.8	Riser
Other (Tandem, etc.)	8.2	All types

According to Table 2, roughly 45 percent of new bicycles were sold with riser or high-riser handlebars, and roughly 45 percent were sold with flat handlebars. While the types of handlebars sold on about 8 percent of the new bicycles could not be determined with any specificity (i.e., the category of bicycle type described as "other"), only about 1 to 2 percent of bicycles appear to have been sold with drop handlebars.

3. Retail Prices

Prices of bicycle handlebars appear to be a function primarily of type of material used for construction. "Aero" bars usually are more expensive than flat, riser, or drop bars. Generally (but not always), more expensive components are used on more expensive bicycles[46]. Internet prices range from about $10 to over $200.

4. Bicycle Use

The results of a national survey of U.S. bicycle riders conducted in 1998 showed that an estimated 85.3 million people rode bicycles that year.[47] This was an increase of about 27 percent from an estimated 66.9 million riders in 1991. Rider ages in 1998 ranged from 2 to 75 years. About 38 percent of all riders, or 32 million, were under 16 years old.

Comparing all age groups, riders under the age of 16 years rode their bicycles most frequently, with the average riding time being about 300 hours for the year. Riders in this age group rode most frequently on sidewalks, playgrounds, and neighborhood streets with low traffic volume.

The average riding time for riders in the 16 - 24 year old age group was about 200 hours in 1998. These riders were more likely than children to ride on streets or highways with a high volume of traffic. They also rode on bike paths and unpaved surfaces.

Adult riders in the age 25 and older category rode an average of about 130 hours during 1998. These riders frequently rode on major streets or highways with a high volume of traffic or on bike paths.

C. Anticipated Production, Consumption, and Foreign Trade

According to the U.S. Department of Commerce, growth in the bicycle and components industries is expected to be about 1 percent a year for the next five years.[48] Demographics are expected to play a large role; the increase in the number of children aged 5 through 14 years is expected to be lower than population growth as a whole through 2004. Historically, U.S. shipments of bicycles have tended to be correlated with growth in this age group. However, the bicycle industry also is closely aligned with the business cycle;[49] as a result, the current uncertain status of the U.S. economy may impact the near-term growth of the bicycle industry and thus, the growth of the handlebar market.

IV. Summary

Bicycle handlebars are produced in a variety of shapes and materials. They are produced using metal fabrication or composite manufacturing methods. Bicycle manufacturers make, assemble, or source the production of, the bicycle frame and then either make or purchase the components to attach to the frame. There are about 80 domestic manufacturers of handlebars.

Handlebars are part of the original equipment on a bicycle, and components for replacement or upgrade (the aftermarket) are sold at specialty bicycle shops. They are not sold through mass merchandise or sporting goods stores. The retail price of handlebars ranges from about $10 to $200, with price a function of the type of material that is used to make the handlebars.

About 21 million bicycles were sold in 2000, with most of those being imported. It is estimated that about 45 percent were equipped with high riser bars, about 45 percent with flat bars, and about 1 percent with drop bars. BMX and juvenile bicycles were sold primarily with riser or high-riser handlebars. Mountain bicycles were sold primarily with flat handlebars, although trail or light-duty mountain bicycles are sold with riser and high-riser handlebars as well as flat.

ENDNOTES

[1] Allen St. John, Bicycling for Dummies, Foster City, California, IDG Books Worldwide, Inc., c.1999, p.44.

[2] For a description of the various types of bicycles, see Appendix C.

[3] A recent innovation is the use of flat bars on road bicycles. See Matt Wiebe, "Scratch that Niche: 2002 Sneak Peek", *Bicycle Retailer and Industry News*, August 1, 2001, Volume 10, Number 13, p.1.

[4] Wiebe, op. cit. See also http://www.wylder.com/components04.htm. Other WSD bicycle components also are being manufactured and marketed.

[5] See note 2, above.

[6] Allen St. John, op.cit., p.20.

[7] Sheldon Brown, Harris Cyclery, Newton, Massachusetts, "Sheldon Brown's Bicycle Glossary", http://www.sheldonbrown.com//glossary.html and http://www.sheldonbrown.com//gloss_a.html#anatomic.

[8] Allen St. John, op. cit., p.20.

[9] Sheldon Brown, op. cit., http://www.sheldonbrown.com/gloss_d.html#dropbar.

[10] Ibid., http://www.sheldonbrown.com//gloss_a.html#aerobars.

[11] Allen St. John, op.cit., p.45.

[12] Sheldon Brown, op.cit., http://www.sheldonbrown.com//gloss_a.html#aerobars.

[13] Ibid. Also see Rivendell Bicycles Works, Inc. http://www.rivendellbicycles.com/webalog/handlebars_stems_tape/16027.html, and Drew Saunders, http://www.stanford.edu/dru.moustache.html.

[14] Sheldon Brown, op. cit., http://www.sheldonbrown.com//gloss_bo-z.html#bullmoose.

[15] See Daniel Boone Cycles, Inc., http://www.danielboonecycles.com/components.php3.

[16] This section relies extensively on the following: Dr. Alex Kalamkarov et al., "Composite Bicycle Frame", Technical University of Nova Scotia, Mechanical Engineering Design Project, March 29, 1997, http://poisson.me.dal.ca/Design_projs/96_97/composite/; 3T Tecno Tubo Torino, "The Manufacture of Handlebar", http://www.3ttt.com/english/the_manufacture/centro_manubrrio.htm ; Easton Bike Components, Inc., "Fabrication Instructions for 6061 and 7075 Tube Sets", http://www.eastonbike.com/TECH_FAQ/fab_inst.html; Scot Nicol, "Intro to Composites", Zipp Speed Weaponry, Inc., http://www.zipp.com/technical_composites.html ; and Calfee Design, "Technical White Paper", Santa Cruz, California, http://www.calfeedesign.com/twp.txt.

[17] See Bontrager Komponents, "Buying a New Road Bike? Here's All You Need to Know", http://bontrager.com/komponents/komponents_04.html,; Southwest Bicycles, Arizona, www.southwestbicycles.com., and Michigan State University, "MSM 481Project Bicycle: Frame Team", Brain VanDragt, Manager, found at "Composites: Applications: Bicycles" in http://www.about.com.

[18] Sheldon Brown, op.cit., http://www.sheldonbrown.com/gloss_h.html#handlebar.

[19] Calfee Design, op. cit.

[20] Jim Spadaccini, "Science of Cycling: Frames & Materials", The Exploratorium, Palace of Fine Arts, San Francisco, California, www.exploratorium.edu/cycling/frames2.html.

[21] Adam Vincent, "Taiwan Market Changes to Meet Future", *Bicycle Retailer & Industry News*, March 15, 2001, p. 35.

[22] Kalamkarov, op.cit., p.4.

[23] Nicol, op. cit.

[24] In general, tubing for handlebars still is round. The other shapes are used for other pieces of the bicycle frame or other components.

[25] Calfee Design, op.cit.

[26] Metal Improvement Company, "Shot Peening", http://www.shotpeen.com/shot.htm.

[27] National Bicycle Dealers Association, "A Look at the Bicycle Industry's Vital Statistics", *2000 NBDA Statpak, Stats Overview,* http://www.nbda.com/statpak.htm.

[28] Bicycle Retailer and Industry news, April 15, 2001, advertisement for Neco parts, Chiih Chinn Industrial Co., Ltd., p. 16.

[29] Kristy B. Arbogast, Otoya J. Cohen, and Flaura Koplin Winston, "Protecting the Child's Abdomen: A Retractable Bicycle Handlebar", Correspondence from Flaura Koplin Winston, The Children's Hospital of Philadelphia, December 18, 2000, and in *Accident Analysis and Prevention*, Vol. 33 (6), (2001) pp. 753-757.

[30] SRAM Corporation, Chicago, Illinois, www.sram.com/product/featured/html/smartbar/index.asp. There may be similar handlebars being marketed by other manufacturers or handlebars that incorporate one or more of the SRAM features being manufactured.

[31] "Strida Folding Handlebars Shrink Bikes", *Bicycle Retailer and Industry News*, March 1, 2001, p. 26.

[32] The McGraw-Hill Companies and the International Trade Administration, U.S. Department of Commerce, "Bicycles and Parts", U.S. Industry & Trade Outlook 2000, c.2000, p.39-17.

[33] Idem.

[34] Erik Layland, "Ritchey's Mountain Bar – Light Enough and Good Enough", http://www.dirtworld.com/articles/reviews_components233.htm.

[35] "Statistics", *Bicycle Retailer and Industry News* online, http://www.bicycleretailer.com/mainmenu.htm, and National Bicycle Dealers Association, op.cit., "Two Distribution Industries, Not One".

[36] National Bicycle Dealers Association, op.cit. "Two Distribution Industries, Not One" and "the Professional Dealer" and The McGraw-Hill Companies and the International Trade Administration, U.S. Department of Commerce, op.cit., p.39-16.

[37] Jay Townley & Associates, LLC. Lyndon Station, WI: "U.S. Specialty Bicycle Retailer Population by Region, June 2001 vs. May 2001", http://www.jaytownley.com/jaytown/html/success2.htm.

[38] National Bicycle Dealers Association, op. cit., "The Professional Dealer".

[39] Idem.

[40] Todd Ackert, representative for True Precision Components, Inc. as quoted in Lou Mazzante, "True Precision is Ready to Tackle Bicycle Market", *Bicycle Retailer & Industry News*, March 15, 2001, p.41.

[41] The McGraw-Hill Companies and the International Trade Administration, U.S. Department of Commerce, op.cit., p. 39-18.

[42] Ibid., p. 39-16.

[43] Matt Wiebe, "Bike Market Sets Record, Exceeds 20 Million Units," *Bicycle Retailer and Industry News*, April1, 2001, Volume 10, Number 5, p. 1.

[44] "Statistics", *Bicycle Retailer and Industry News Online,* www.bicycleretailer.com/mainmenu.htm, National Bicycle Dealers Association, op.cit., "Specialty Bicycle Sales:YTD August 2000", and Lou Mazzante, "Industry Gets a Glimpse of Mass Market Figures", Bicycle Retailer and Industry News, March 1, 2001, Volume 10, Number 3, p.1.

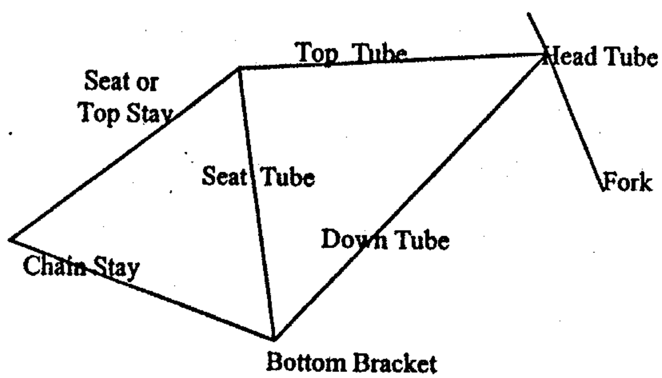
[45] Mountain bicycles accounted for nearly 85 percent of the bicycles in this category.

[46] Dallas Hudgens, "Different Spokes", *The Washington Post Weekend*, April 13, 2001, p.32.

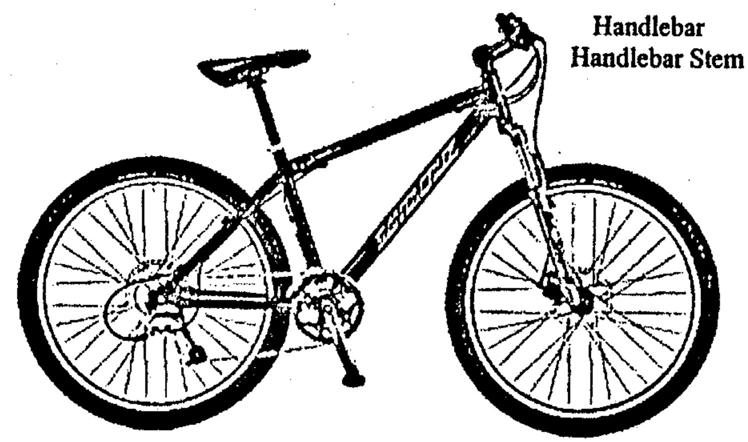
[47] Gregory B. Rodgers, "Bicycle and Bicycle Helmet Use Patterns in the United States in 1998", *Journal of Safety Research*, Volume 31, Number 3, Fall 2000, pp. 149-158.

[48] U.S. Department of Commerce, op.cit., p. 39-17.

[49] Ibid., p.39-16.

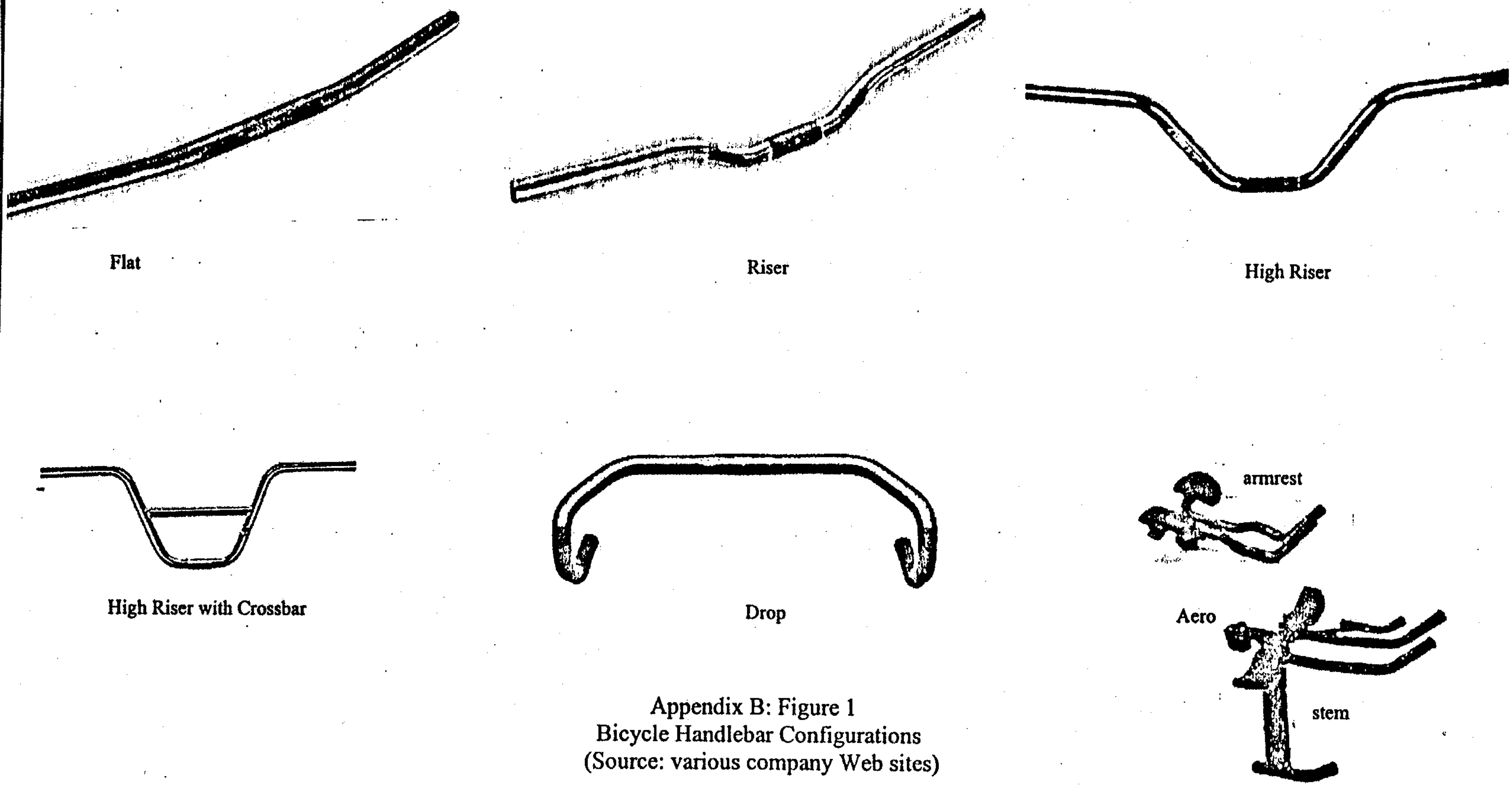


BICYCLE FRAME
(A typical or common bicycle frame consists of the head tube, top tube, seat tube, down tube, seat or top stay, chain stay, bottom bracket, and fork.)

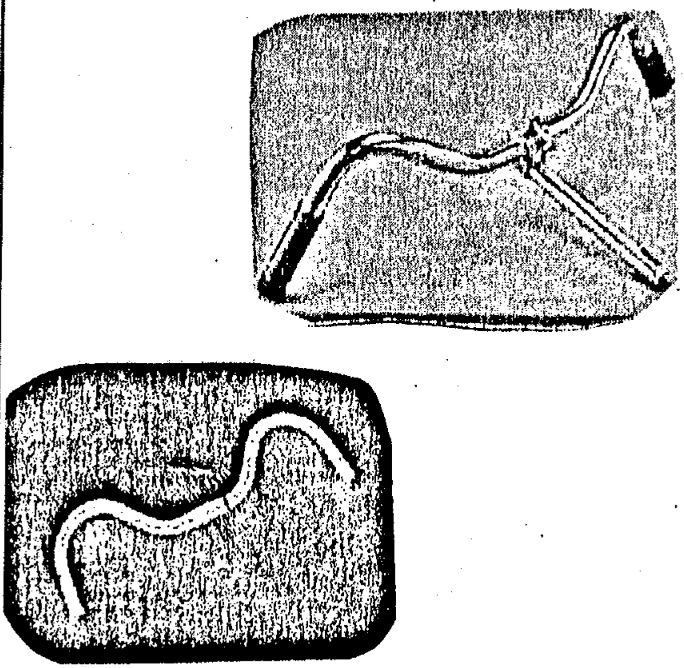


BICYCLE FRAME AND SELECTED COMPONENTS
(Source: www.santacruzmtb.com)

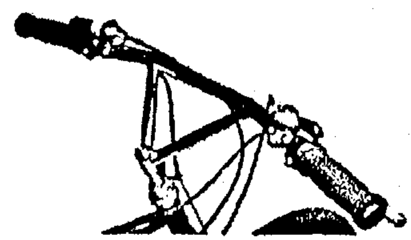
Appendix A: Bicycle Frame and Selected Components



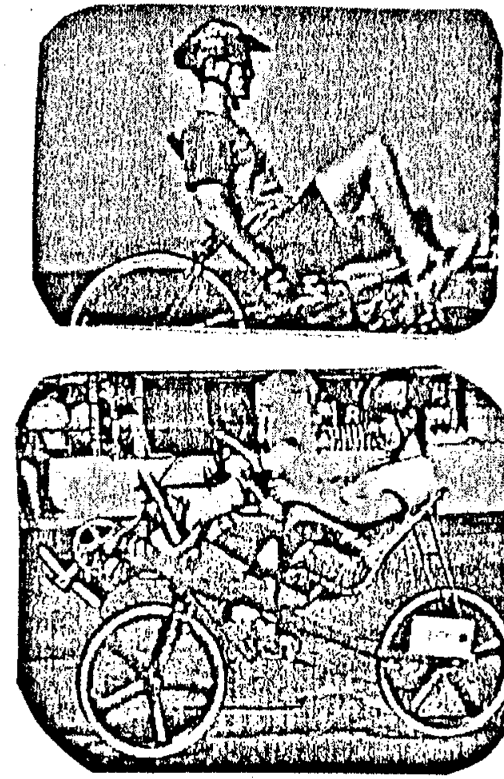
Appendix B: Figure 1
Bicycle Handlebar Configurations
(Source: various company Web sites)



Moustache



Bull Moose



Recumbent

Appendix B: Figure 2
Bicycle Handlebar Configurations
(Source: company Web sites)

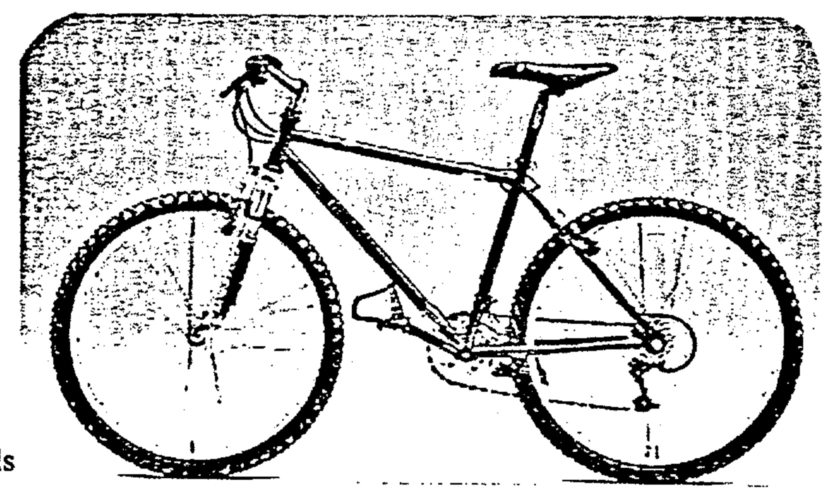
Appendix C[1]
Bicycles Types

The bicycles that are sold at retail are categorized into the following types:

Mountain	Tandem
Trail or Light-Duty Mountain	Recumbent
Comfort	Folding
Road, Touring, or "Comfort" Road	Electric-Assist
Hybrid or "Cross"	Adult Three-Wheeler
Cruiser or City	Free Style, Free Agent, or Trick
Juvenile	Jumping
BMX or Dirt	Miniature or Circus

The most common bicycles, in terms of sales, are those listed in the left column. General characteristics and pictures of all of these bicycles are shown below.

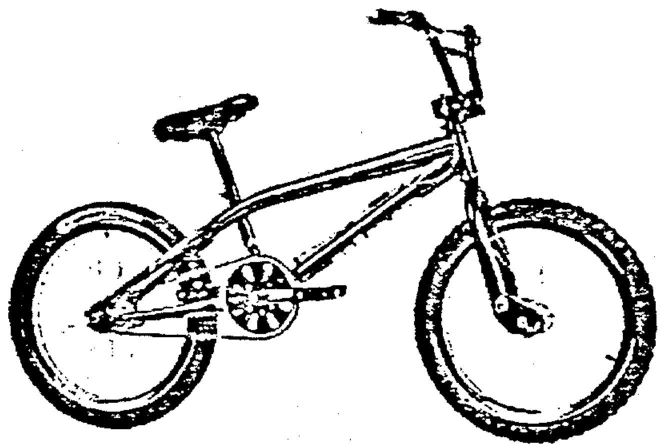
MOUNTAIN



- 26" wheels
- 21-27 gears
- fat, knobby tires; often has bar ends
- for use on rough off-road, rugged terrain (but often used on-road)
- frame built for ground clearance
- some have front suspension, some have full suspension
- versions: downhill, freeride, trials, single speed mountain
- primarily flat handlebars

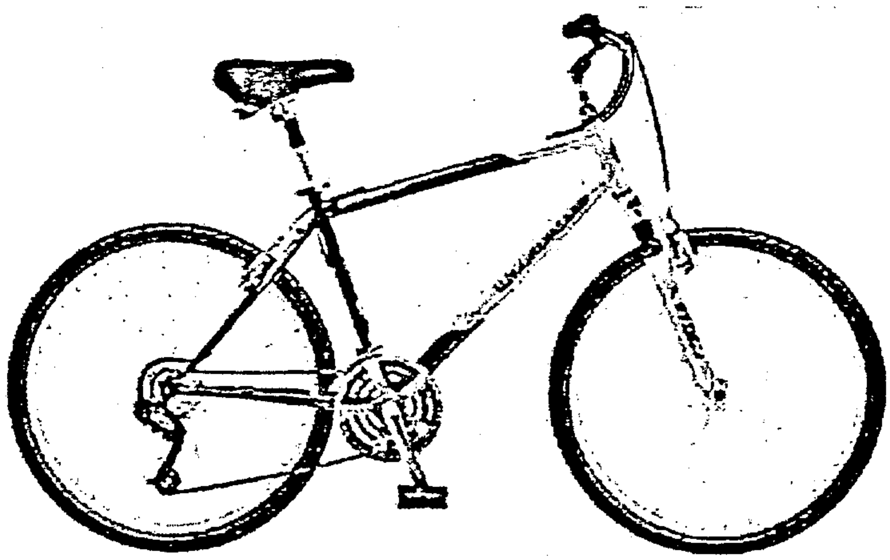
[1] The material in this Appendix is based on: "The Different Types of Bicycles", http://www.bikesmottoys.com/diffBIkes.htm ; Allen St. John, Bicycling for Dummies, Foster City, California: IDG Books Worldwide, c. 1999, pp. 22 - 37; Dallas Hidgens, "Different Spokes", *The Washington Post Weekend*, April 13, 2001, p.31; National Bicycle Dealers Association, *2000 NBDA Statpak*, "Specialty Bicycle Sales:YTD August 2000", http://www/nbda.com/statpak.htm; Lou Mazzante, "Circus Bikes: Are They for Clowns or Serious Retailers?", *Bicycle Retailer and Industry News*, July 15, 2001, p.1; and various corporate Web sites.

TRAIL OR LIGHT-DUTY MOUNTAIN



- 26" wheels (sometimes 20" and 24" wheels for older children)
- 21 - 24 gears
- similar looks and features as mountain bikes, but usually not as light or rugged
- intended for trail or road use
- often used by commuters or recreational riders
- riser, high-riser, or flat handlebars

COMFORT



- 26 " wheels
- 7 - 24 gears
- for recreational, trail, or commuter use
- wide pedals, softer saddles, shock absorbing front forks, handlebar stems and seat posts
- similar to mountain bikes, but with less distance between seats and handlebars
- front end is higher for more upright seating; primarily flat handlebars