PROTECTIVE HEADWEAR TO REDUCE RISK OF INJURY

Applicants: Wayne H. Tuttle, Torrance, CA (US);
Lisa C. Whitaker, Torrance, CA (US)

Inventors: Wayne H. Tuttle, Torrance, CA (US);
Lisa C. Whitaker, Torrance, CA (US)

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ABSTRACT
A helmet configured to protect a human head against mild traumatic brain injury upon impact includes an outer shell and a liner consisting of fluid fillable flexible fluid chambers fluidly connected to each other by fluid connections. The fluid chambers being spaced around the circumference of the helmet and configured to fill a space between the head and the outer shell when the helmet is positioned on the head. Impact resistant flexible pads are also in the liner and are spaced around an inner circumference of the outer shell adjacent to each of the fluid fillable flexible fluid chambers. A flexible inner shell inside the liner is configured to fit closely on the head. The flexible fluid chambers are configured to compress in response to impacting of the helmet on an impact side and to force liquids through the fluid connections to inflate other fluid chambers inside the helmet thereby cushioning the head against a rebound impact on the inside of the helmet.
FORMING OUTER SHELL

FORMING PAIRS OF FLEXIBLE FLUID CHAMBERS

CONNECTING EACH PAIR OF FLEXIBLE FLUID CHAMBERS BY FLUID PASSAGE WAYS

FILLING THE INTERCONNECTED FLEXIBLE FLUID CHAMBERS WITH FLUID

FORMING IMPACT RESISTANT FLEXIBLE PADS THAT FIT BETWEEN THE FLEXIBLE FLUID CHAMBERS

FORMING AN INNER SHELL

ATTACHING THE INTERCONNECTED FLEXIBLE FLUID CHAMBERS AND FLEXIBLE PADS TO THE INNER AND OUTER SHELLS TO FORM A HELMET

FORMING AND ATTACHING A CHIN STRAP TO THE INNER AND OUTER SHELLS OF THE HELMET

Fig. 8
PROTECTIVE HEADWEAR TO REDUCE RISK OF INJURY

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This application is a continuation-in-part of U.S. application Ser. No. 15/227,593 filed Aug. 3, 2016 for “Protective Headwear to Reduce Risk of Injury” by W. H. Tuttle and L. C. Whittaker, which in turn claims the benefit of U.S. Provisional Application No. 62/203,152 filed Aug. 10, 2015, both of which are hereby incorporated by reference in their entirety.

BACKGROUND

[0002] This invention relates to protective head gear. In particular the invention is a helmet designed to protect against mild traumatic brain injury (MTBI).

[0003] Traumatic brain injuries can occur when the head experiences accelerations or decelerations that cause the brain to move within the skull and generate physical damage to structures within the brain. The accelerations associated with traumatic brain injuries can be linear, rotational, or complex combinations of accelerations. The brain is a soft gelatinous organ housed within the skull surrounded by liquid. During a high speed acceleration event the brain can move within the skull and impact the skull and subsequently rebound and experience additional impact with the skull on the opposite side of the brain (coup-contrecoup). In lower speed acceleration events the brain may not impact the skull, but can still sustain damage as the internal structures of the brain slide past each other and damage neural interconnections.

[0004] These injuries are generally referred to as mild traumatic brain injuries (MTBI). The word mild refers to the manner of impact and not the severity of the injury. The term concussion is often used to describe mild traumatic brain injuries. Symptoms of concussion can include loss of consciousness, headaches, confusion, temporary cognitive impairment, vertigo and balance problems. More severe mild traumatic brain injuries can cause permanent impairment and increased risk of serious long term medical complications. Repeated mild traumatic brain injuries are associated with additional long term health risks including neuro degenerative brain diseases such as chronic traumatic encephalopathy which has been found in former professional athletes who have experienced multiple concussions over their careers.

[0005] Studies of the causes of concussions have demonstrated that a wide range of acceleration forces can cause concussions. For example, studies indicate that American football players regularly sustain accelerations of 20 to 180 Gs with various injury outcomes. In general the higher the G-force, the greater the injury, but some athletes have experienced concussions at impact forces below 60 G while others have been free of concussion injury at impact forces in excess of 100 G. 60 G is often considered a level below which it is unlikely that a concussive injury will occur.

SUMMARY

[0006] A helmet configured to protect a human head against mild traumatic brain injury upon impact includes an outer shell and a liner consisting of fluid fillable flexible fluid chambers fluidly connected to each other by fluid connections. The fluid chambers being spaced around the circumference of the helmet and configured to fill a space between the head and the outer shell when the helmet is positioned on the head. Impact resistant flexible pads are also in the liner and are spaced around an inner circumference of the outer shell adjacent to each of the fluid fillable flexible fluid chambers. A flexible inner shell inside the liner is configured to fit closely on the head. The flexible fluid chambers are configured to compress in response to impacting the helmet on an impact side and to force liquids through the fluid connections to inflate other fluid chambers inside the helmet thereby cushioning the head against a rebound impact on the inside of the helmet.

[0007] In an embodiment, a method of forming a helmet to protect a human head against mild traumatic brain injury upon impact includes forming an outer shell larger than the head and forming a liner consisting of fluid fillable flexible fluid chambers that fit inside the outer shell configured to fill a space between the head and the outer shell when the helmet is positioned on the head. The method further includes connecting the flexible fluid chambers with fluid connections such that at least two fluid chambers are interconnected. The method further includes filling the interconnected flexible fluid chambers with fluid and forming impact resistant flexible pads inside and spaced around the inner circumference of the outer shell adjacent to each of the flexible fluid chambers. The method further includes forming a flexible inner shell inside the liner configured to fit closely on the head and attaching the flexible fluid chambers and flexible pads to the inner and outer shells to form the helmet such that the flexible fluid chambers are configured to compress in response to impacting the helmet on an impact side and force liquid through the fluid connections to inflate other fluid chambers in the helmet thereby cushioning the head against a rebound impact on the inside of the helmet. The helmet is finished by attaching a chinstrap and fastener to the helmet.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 is a schematic cross-section of a helmet according to an embodiment of the invention on a human head.

[0009] FIG. 2 is a top view of the liner of the helmet with the outer shell removed.

[0010] FIG. 3 is a side view of a helmet with a strap.

[0011] FIG. 4A is a top view of an embodiment of the liner of the helmet with the head centered in the helmet.

[0012] FIG. 4B is a top view of the embodiment of FIG. 4A with the head rotated 25° counterclockwise around the central axis of the brain.

[0013] FIG. 5A is a side view of an embodiment of the liner of the helmet positioned on a human head facing right.

[0014] FIG. 5B is a rear view of the embodiment shown in FIG. 5A.

[0015] FIG. 6A is a side view of the embodiment of the helmet positioned on a human head facing right.

[0016] FIG. 6B is a rear view of the embodiment shown in FIG. 6A.

[0017] FIG. 7 is a side view of an embodiment of the helmet positioned on a human head.

[0018] FIG. 8 is a method of forming a helmet according to an embodiment of the invention.
DETAILED DESCRIPTION

[0019] The present invention relates to protective headwear typically referred to as a helmet. Such a helmet fulfills the task of protecting a person’s head from injury in the case of impact with other objects. Protective headwear is used in a variety of military, industrial, and sporting activities to prevent, or reduce the severity of, traumatic injury caused by foreseeable impacts associated with those activities. For example, participants in many sports such as American football, baseball, cycling, equestrian, field hockey, ice hockey, lacrosse, skiing, snowboarding, surfing, wakeboarding, and water skiing routinely wear protective helmets to reduce the risk and severity of head injuries in general and traumatic brain injury in particular. Additional activities such as automobile racing, motorcycling, and snowmobiling are sports often associated with the use of specialized protective helmets to protect the users from injuries including traumatic brain injuries.

[0020] Studies have demonstrated that the natural resonant frequency of the brain within the skull is approximately 15 Hz. If an impact generates accelerations that excite brain motions at or near its natural resonant frequency, the motions and impacts of the brain within the skull may be amplified and the damage caused can be greater than would otherwise be expected for the G-force experienced. Thus there is a need for protective helmets that will reduce the accelerations experienced by the users’ head and reduce the tendency of an impact event to amplify the brain’s motion at or near its natural resonant frequency. Prior art has been generally good at limiting the peak acceleration forces experienced during impact. One method well known in the prior art is the use of a liner made from non-resilient compressible materials that permanently deform at selected force levels. This deformation absorbs energy and establishes the maximum acceleration level that can be experienced during the time that the material is undergoing compression. One limitation of such helmets is that by only establishing a peak value, the helmets can offer insufficient protection from lower force accelerations that trigger resonant amplifications of brain motions within the skull. An additional limitation of such designs is that after they have functioned, the liner material has lost its protective capacity and must be replaced. The materials may not appear to have been depleted and users may wrongly continue to rely on the helmet for additional impact protection.

[0021] In a typical concussive event, the head is rapidly decelerated, causing the brain to move within the skull. The brain is attached near its bottom-center and can swing about this fulcrum. As the brain moves into contact with the skull, it compresses and rebounds, contacting the opposite side of the skull. This can cause two injury sites in the brain and is referred to as a “coup-contrecoup” injury. Since the brain can be considered as an underdamped mechanical system, a method of protection against coup-contrecoup injury is to supply damping to the system, particularly at the resonant frequency of the brain.

[0022] There is a need for protective helmets that can reduce the impact force transferred to a user’s head in terms of reducing the peak force experienced and to control the effective frequency of the energy transfer to a value that does not tend to excite brain motion amplification at its resonant frequency.

[0023] A non-limiting embodiment of the invention is shown in FIG. 1. FIG. 1 is a schematic cross-section of helmet system 10 on human head 12 containing brain 14. Helmet system 10 may include outer shell 16, a middle liner containing fluid filled flexible fluid chambers such as bladders 18 and interconnecting fluid passageways 20, and inner liner 22. The energy absorbing mechanism of helmet system 10 is as follows. If the user is travelling forward and experiences a frontal head-on impact with an object, head 12 will continue to move forward generating increased pressure in fluid filled bladders 18A at the forehead. The higher pressure will force fluid from bladder 18A to bladder 18E at the rear of head 12 through fluid passageway 20. The fluid viscosity and dimensions of fluid passageway 20 may be sized to establish a rate of fluid transfer during acceleration that may absorb impact energy and lengthen the time of the energy absorption process to reduce the effective frequency of the energy transfer. This action may spread the force over time and distance, to reduce the peak force experienced by brain 14. It may also increase the time over which the brain experiences the force to well above the 33 millisecond half wave period of the approximately 15 Hz resonant frequency of the brain.

[0024] An additional feature of helmet system 10 is shown in FIG. 2. FIG. 2 is a schematic top view of helmet system 10 with outer shell 16 removed. Compressible material 24 may be placed on each side of flexible fluid chambers 18A-18F in the middle liner. Inner liner 22 forms the inside layer of helmet system 10. The purpose of these compressible devices is to center head 12 within outer shell 16 between impact events. Since the flexible fluid chambers are distributed around the circumference of head 12, head 12 may be protected against the peak force of torsional accelerations as well as more complicated forms of impact. The compressible strengths of compressible material 24 may be from about 5 G to 10 G in some embodiments.

[0025] Fluid passageways 20 may be sized based on fluid viscosity to establish a rate of fluid transfer during acceleration or deceleration to absorb impact energy and to increase the time of the energy absorption process as mentioned above. In an embodiment, the fluid passageways may be flexible tubing. In another embodiment, the flexible fluid chambers and fluid interconnections may be formed from two or more sheets of a flexible polymeric material by welding patterns in the sheets defining the chambers and associated fluid interconnections.

[0026] A side view of an embodiment of the invention is shown in FIG. 3. Outer shell 16 of helmet 10 is shown attached to human head 12 by chinstrap 26 and fastener 28. Releasing fastener 28 enables the wearer to remove helmet 10 from head 12. Other forms of securing helmet 10 to head 12 may be used depending on the requirements of the application.

[0027] In another non-limiting embodiment, the fluid passageways may be arranged such that the damping is optimized for impact directions that are not radial to the center of the head, but are instead torsional around the axis of the head. FIG. 4A shows a top view of helmet system 130 on human head 112 inside helmet shell 116 with head 112 in a normal symmetrical orientation with respect to helmet shell 116. Middle inner elements of helmet system 130 comprise flexible fluid chambers 118, interconnecting fluid passageways 120, and compressible material 124 placed between the flexible fluid chambers 118 to center head 112 within outer shell 116 (not shown) between impact events. Inner liner 122 forms the inside layer of the helmet system 130. In
contrast to the fluid passageway layout of FIG. 2, fluid passageways 120 may be aligned parallel to and perpendicular to the major longitudinal axis of helmet shell 116.

[0028] FIG. 4B shows human head 112 rotated 25° counter-clockwise with respect to the normal orientation as a result of a torsional impact to helmet system 130. Flexible fluid chambers 118D and 118I have been compressed forcing fluid through passageways 120 to inflate chambers 118F and 118B, thereby cushioning head 112 when it rebounds after impact. A similar result occurs when head 112 is rotated in a clockwise fashion after an appropriate torsional impact in an opposite direction. Such an arrangement is beneficial in certain sports and activities where the wearer is likely to experience off-angle impacts such as often seen in American football. These impacts generate rapid rotations of the head causing torsional distortion of the brain and resulting in MTBI even with lower levels of acceleration in the x, y, z direction. When the helmet is exposed to rotational forces, the hydraulic damping system described herein may reduce the instantaneous force experienced by the wearer to a controlled level and increase the time over which the acceleration is experienced. This reduces the torsional forces coupled to the brain and may reduce the chance of MTBI caused by these forces.

[0029] In another embodiment, the fluid filled damping elements of the invention may be made from at least three interconnected fluid chambers. An example is shown in FIGS. 5A and 5B. In helmet system 230, the damping system is optimized for forces applied to the top of the head as indicated by arrow A and interacts with the spine as a downward compression along the Z-axis of the head. In this example, top chamber 218A communicates with two other chambers, 218B and 218C, arranged around the bottom perimeter of helmet shell 216. An inner liner is not shown in FIGS. 5A and 5B. Such an arrangement may be beneficial in certain sports activities where the wearer is likely to experience impacts to the top of the head such as American football, bicycling, snow skiing and others. In American football, for example, two players running toward each other with their heads lowered may experience head to head impact. Fluid forced from top chamber 218A to lower chambers 218B and 218C over a time interval dependent on fluid flow rates and fluid interconnections 220 may positively impact the impact dynamics experienced by brain 214. As mentioned earlier, fluid interconnections between other fluid chambers in the helmet may also affect damping of radial and rotational accelerations induced by off-center impact events.

[0030] In another embodiment, the fluid chambers may have more than a single size of fluid communication connections. Such secondary communication paths may allow different levels of restriction to motion in different directions. This may enable a designer to tailor the directional damping response to anticipated forces experienced by the wearer. An example of this is shown in FIG. 6A and 6B which are a side view and a rear view of the embodiment of helmet system 330 positioned on human head 312 respectively. Top fluid chamber 318A is connected to right and left bottom fluid chambers 318B and 318C respectively by fluid interconnections 320 and to rear fluid chamber 318D by fluid interconnection 321. In the particular case of helmet system 330, rear fluid interconnection 321 has a smaller diameter than fluid interconnection 320 which will provide a different dynamic response of chamber 318D to the other two chambers thereby offering tunable response of the fluid chamber system to an impact. An inner liner is not shown in FIGS. 6A and 6B.

[0031] In an embodiment, the fluids in some or all of the fluid chambers may be dilant fluids. Dilant fluids are non-Newtonian in which the viscosity increases with the rate of shear strain. In the helmets of the invention, these fluids provide greater damping when the applied acceleration forces are greater. This enables the helmet to be useful over a greater range of anticipated accelerations. The remaining design elements of other embodiments may remain unchanged when this variable viscosity fluid embodiment is incorporated.

[0032] In other embodiments, some or all of the fluid chamber sets may have a higher or lower viscosity than other sets within the helmet. This may provide the ability to have different damping rates and different accelerations directions while maintaining more constant fluid chamber thicknesses.

[0033] In another embodiment, the helmet may not incorporate a hard shell 16. Hard shell 16 may be necessary when likely objects of impact necessitate a hard shell to resist transference of energy from a rigid shape with reduced surface contact area. Other uses may not anticipate this type of impact event and therefore may not require a hard shell. A hard shell may reduce protection in certain situations. For example, in wakeboarding and waterskiing a likely collision with water will occur at speeds in excess of 20 mph. At these speeds there is a risk that the hard shell of a helmet may catch its edge on the water surface transferring breaking forces to the head and neck. In this case a risk of whiplash injuries may outweigh the risk of impacts with sharp surfaces that would have required the use of hard shell protection. As impact velocity increases, a requirement for protection from impact with the surface of the water may become important and the hard shell embodiment may be preferred.

[0034] In a soft shell embodiment, the use of interconnected fluid filled chambers, remains the same, but the shell may be a form-fitting compliant cover. This cover may not allow the development of significant hydrodynamic forces at the interface of a helmet and water surface. This may be a preferred embodiment for use in sports including surfing, wakeboarding, wakesurfing, waterskiing and other compliant shell helmet examples.

[0035] Hybrid embodiments combining portions of hard and soft shell embodiments may also be used for watersports based on anticipated velocities and likely impact surfaces. A typical example of an activity where the merits of soft shell and hard shell designs may be considered is cable towed wakeboarding where there are solid objects such as metal rails in to which the rider may collide. Based on likely impact velocities and impact surfaces the selection of a hard shell or a hybrid embodiment may be preferred.

[0036] An example of a hybrid embodiment is a helmet that contains both the hydraulic system described herein combined with a helmet liner made from non-resilient compressible materials that permanently deforms at force levels from about 60 G to about 150 G. In this embodiment, the hydraulic system may protect the head in lower speed impacts while the non-resilient system may provide additional protection in higher speed impacts by setting a maximum acceleration level for the protecting shell to deform and absorb impact forces. An example of this embodiment is shown in FIG. 7. Hybrid helmet system 430 comprises
non-resilient crushable inner liner 423 supporting fluid filled flexible fluid chambers 418A and 418E connected by fluid passageway 420. Flexible outer liner 422 closely covers the hydraulic impact resistance system and the G resistant crushable inner liner 423 providing impact absorbing protection to impacts exceeding G. In all cases overall helmet performance may be improved because of the reduced initial acceleration and impulse lengthening time associated with the hydraulic helmet liner system.

Candidate materials for outer shell 16 of the various embodiments described herein may include impact resistant materials such as polycarbonate, fiberglass, or Kevlar. An acceptable hardness for an impact resistant outer shell may be greater than Rockwell N62. Candidate materials for flexible inner or outer shells may be elastomer, elastomeric polymer, polymer impregnated fabric, elastomer impregnated fabric, laminated fabric, polymer fiber composite, leather, synthetic leather or others known in the art. Candidate materials for flexible pads 24 between flexible fluid chambers 18 may include open cell and closed cell foam made from synthetic materials including silicone and polyurethane. Candidate materials for non-resilient crushable inner liner 423 may include expanded polystyrene, expanded polypropylene, or expanded polyurethane.

In all embodiments described herein, the damping forces may be adjusted by means of fluid flow control. The dynamic interactions of hydraulic systems are well established and understood, therefore only a brief description of how this invention uses hydraulic means to reduce injurious forces is provided herein.

There is a relationship between applied force and hydraulic pressure that is based on the surface area of the fluid chamber. Simply put, if the chamber has 2 in.² of surface and a force of 10 lbs. is applied, a hydraulic pressure of 5 psi. is generated. Increasing the chamber surface area reduces the hydraulic pressure while increasing the volume of fluid being displaced. Reducing the surface area likewise increases the resultant pressure while reducing the volume of fluid being displaced. Using this relationship, a designer can select the quality and sizes of the chambers to control the hydraulic pressure during a protective event.

There is a relationship between the size of the communication channel (tube) and the flow at any given pressure. Simply put, for any given pressure a larger tube will allow more fluid and a smaller tube will allow less fluid to flow.

Finally there is a relationship between fluid viscosity and flow. The thicker the fluid the slower the fluid will flow through a given size of tube at a given pressure.

In practice, the size of individual fluid chambers is based on the strength of the chamber materials to ensure that the parts do not fail. The fluid is selected based on safety, cost and availability, viscosity, as well as compatibility with the materials used and the operating environment of the helmets. The communication tubes are sized based on the desired flow rate. The hydraulic helmet system described herein is designed to reduce the peak force levels and lengthen the period over which the forces are experienced such that stimulation of natural resonant frequency of the brain is reduced. Since there are multiple energy dissipation pathways, the protection can be adjusted to any number of requirements based on the particular impact characteristics expected, which will differ in different sports and applications. The specific arrangement of fluid chambers, communication channels, and fluid composition will be different in helmets optimized for different sports. A helmet designed for use in bicycling may not be suitable for use in American football and vice versa.

A method of forming helmet 10 according to an embodiment of the invention is shown in FIG. 8. Method 530 comprises forming outer shell 16 (step 531). Outer shell 16 may be a hard impact resistant shell that is larger than head 12, or may be a flexible shell that is larger than head 12. In an embodiment, a preferred hard impact resistant shell material may be a polycarbonate polymer with a Rockwell M hardness greater than 62. In another embodiment, a preferred flexible shell material may be a synthetic leather. The method may also include forming fluidly connected flexible fluid chambers for installation in the space between the outer and inner shells of the helmet (step 532). The flexible fluid chambers are designed to contain liquids of different viscosities depending on the application. Each fluidly connected flexible fluid chamber group is connected by tubing of various diameters depending on the anticipated functions of the helmet (step 533). Examples of suitable flexible tubing include nylon, PVC, silicone, and others. In an embodiment, the chambers and interconnected tubes may be made from the same sheets of material with the size and shape of the chambers and fluid passageways established by pattern welding sheets of the material together. The interconnected bladders may then be filled with fluid (step 534). Suitable fluids for the invention include water, glycerin, mineral oils, ethylene glycol and others known and not known in the art. Flexible pads may then be formed for installation next to the flexible fluid chambers to fix the location of the flexible fluid chambers in the space between the outer and inner shells of the helmet (step 535). In an embodiment, the pads may be designed to deform under impacts exceeding about 5 G to 10 G. Candidate materials include open cell and closed cell foam made from synthetic materials including silicone and polyurethane. In the next step an inner shell may be formed (step 536). The inner shell may be a flexible material that conforms closely to the head of the wearer. Materials suitable for an inner shell may include the above materials noted for the flexible outer shell.

Assembling the helmet may include attaching interconnected flexible fluid chambers and flexible pads to the outer and inner shells in the space between the shells to form the helmet (step 537). In the final step, a chinstrap and connector may be attached to the outer and inner shells to form the finished helmet (538).

While the invention has been described with reference to an exemplary embodiment(s), it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment(s) disclosed, but that the invention will include all embodiments falling within the scope of the appended claims.

1. A helmet configured to protect a human head against mild traumatic brain injury upon impact comprising:
   an outer shell;
   a liner inside the outer shell, the liner comprising fluid fillable flexible fluid chambers fluidly connected to at
least one other chamber by fluid connections therebe-
tween, wherein the fluid fillable flexible fluid chambers 
are located around a circumference of the helmet and 
configured to fill a space between the head and the outer 
shell when the helmet is positioned on the head; 
impact resistant flexible pads inside and spaced around an 
inner circumference of the outer shell adjacent to each 
of the fluid fillable flexible fluid chambers; and 
a flexible inner shell inside the liner, configured to fit on 
the head; 
the flexible fluid chambers being configured to compress 
in response to impacting of the helmet on an impact 
side, and to force fluids through the fluid connections to 
inflate fluid chambers in other regions of the helmet, 
thereby cushioning the head against a rebound from 
normal impacts, tangential impacts and mixtures 
thereof.

2. The helmet of claim 1, wherein the fluid fillable flexible 
fluid chambers are fluidly connected to at least two other 
fluid chambers by fluid connections therebetween.

3. The helmet of claim 1, wherein the fluid connections 
are sized based on fluid viscosity to establish a rate of fluid 
transfer during impact to absorb impact energy and lengthen 
a time of energy absorption to reduce an effective frequency 
of energy transfer.

4. The helmet of claim 3 wherein the fluids comprise 
dilant fluids.

5. The helmet of claim 1, wherein the outer shell is a hard 
material with a hardness greater than Rockwell M 62.

6. The helmet of claim 4, wherein the outer shell is 
composed of polycarbonate, fiberglass or Kevlar.

7. The helmet of claim 1, wherein the outer shell is a 
compliant material.

8. The helmet of claim 1 wherein the inner shell is an 
impact resistant layer comprising a non-resilient compress-
ible material that permanently deforms at force levels from 
60 G to 150 G.

9. The helmet of claim 1, wherein the impact resistant 
pads are resistant to forces of 5 G to 10 G.

10. The helmet of claim 1, wherein the inner shell is 
composed of elastomer, elastomeric polymer, polymer 
impregnated fabric, elastomer impregnated fabric, laminated 
fabric, polymer fiber composite, leather, synthetic leather or 
mixtures thereof.

11. A method of forming a helmet to protect a human head 
against mild traumatic brain injury upon impact comprising: 
forming an outer shell larger than the head; 
forming a liner comprising fluid fillable flexible fluid 
chambers fluidly connected to at least one other cham-
ber that fit inside the outer shell around the circumfe-
rence of the helmet, the flexible fluid chambers being 
configured to fill a space between the head and the outer 
shell when the helmet is positioned on the head; 
connecting each group of flexible fluid chambers with a 
fluid connection, so that each group of flexible fluid 
chambers is interconnected; 
filling the groups of interconnected flexible fluid cham-
ers with fluid; 
forming impact resistant flexible pads in the liner spaced 
around an inner circumference of the outer shell adja-
cent to each of the flexible fluid chambers; 
forming a flexible inner shell inside the liner, configured 
to fit closely on the head; 
attaching the flexible fluid chambers and flexible pads to 
the inner and outer shells to form the helmet such that 
the flexible fluid chambers are configured to compress 
in response to impacting of the helmet on an impact 
side, and force liquid through the fluid connections to 
inflate other fluid chambers in the helmet, thereby 
cushioning the head against a rebound impact on hel-
met; and 
attaching a chin strap and fastener to the helmet.

12. The helmet of claim 11 wherein the fluid fillable flexible 
fluid chambers are fluidly connected to at least two 
other fluid chambers by fluid connections therebetween.

13. The method of claim 11 wherein the fluid connections 
are sized based on fluid viscosity to establish a rate of fluid 
transfer during impact to absorb impact energy and lengthen 
a time of energy absorption to reduce an effective frequency 
of energy transfer.

14. The method of claim 11 wherein the fluids comprise 
dilant fluids.

15. The method of claim 11, wherein the outer shell material is a hard 
material with a hardness greater than Rockwell M 62.

16. The method of claim 15, wherein the outer shell is 
composed of polycarbonate, fiberglass or Kevlar.

17. The method of claim 11, wherein the outer shell is a 
compliant material.

18. The method of claim 11 wherein the inner shell is an 
impact resistant layer comprising a non-resilient compress-
ible material that permanently deforms at force levels from 
60 G to 150 G.

19. The method of claim 16, wherein the outer shell is 
composed of elastomer, elastomeric polymer, polymer 
impregnated fabric, elastomer impregnated fabric, laminated 
fabric, polymer fiber composite, leather, synthetic leather or 
mixtures thereof.

20. The helmet of claim 11, wherein the impact resistant 
pads are resistant to forces of 5 G to 10 G.

21. The helmet of claim 11, wherein the flexible fluid 
chambers are filled with water, mineral oil, or mixtures of 
water and non-toxic antifreeze liquids.

22. The method of claim 11, wherein the flexible fluid 
chambers and fluid connections are each produced from two 
or more sheets of polymeric material by welding the sheets 
along a pattern defining the flexible fluid chamber and fluid 
connection.