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HEADBAND

Abstract

The present invention relates to a headband for protecting a user's head from impact forces. The headband (**100***a*) comprises a first external layer (**102**) and an opposing second external layer (**108**): an impact absorbing layer (**106**) between the first and second external layers; and a slip layer (**104***a*) positioned between the impact absorbing layer and one of the first and second external layers. Upon the headband receiving an impact, the slip layer facilitates relative movement between the impact absorbing layer and the one of the first and second external layers.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is the U.S. national phase of PCT/GB2022/051356, filed on May 27, 2022, which claims the benefit of United Kingdom Patent Application Number 2107882.9, filed on Jun. 2, 2021, the entire disclosures of both of which are hereby incorporated by reference herein.

FIELD OF THE DISCLOSURE

[0002] The present invention relates to a headband for protecting a user's head/skull and brain from impact forces. In particular, the headband protects a user's skull and brain from both linear and rotational forces sustained through head trauma. Head trauma injures the brain, with the largest stains occurring in the fornix (memory), midbrain (eye movement) and corpus callosum (connecting the two sides of the brain).

[0003] The invention is usable to protect a user's skull and brain from impact forces in contact sports, where brain injuries are common, and for users with increased risk of falls and head trauma.

BACKGROUND

[0004] Brain trauma is a major injury risk in many sports, with potentially very serious consequences in the short and longer term. When the head/skull is subjected to an external force or impact, this force is transmitted to the brain, which causes movement of the brain inside the skull. Sudden rotational acceleration or deceleration of the brain, such as from a high magnitude, concussion-causing hit, may result in tearing of cognitive nerve cells, brain cell death, and disruption of the connected nerve cell networks in the brain, leading to brain trauma.

[0005] With smaller, sub-concussive and asymptomatic repetitive blows to the head; injury occurs to tiny blood vessels in the brain and to the ‘blood brain barrier’, a structure designed to protect the brain by preventing pathogens, toxins, and other solutes in circulating blood from non-selectively crossing into brain tissue. When this structure is damaged by repetitive trauma, an abnormal ‘immune’ mediated inflammatory response is triggered, with the production of neurochemicals. The neurochemicals and inflammatory response should be protective; however, if the brain is subjected to repetitive blows before the protective neurochemicals and inflammatory from an initial head injury have had time to return to normal, any subsequent repetitive head injuries will result in an abnormally exaggerated further production of neurochemicals and an exaggerated inflammatory response. This response is harmful to the brain, damages brain tissue, and eventually leads to the irreversible death of brain cells.

[0006] Every year in English professional rugby, concussion accounts for 20% of all injuries, and in football, as many as 22% of all injuries are concussions or other head-related injuries. Brain trauma and head injuries are significantly underreported in all sports, and there is a large disparity between how different sports protect athletes and deal with participants suffering head injuries in the short and long term.

[0007] Brain trauma does not necessarily require a loss of consciousness or a high-force hit. A blackout only occurs in less than 10% of concussions. Concussion occurs on the rapid displacement and rotation of the cranium and is diagnosed on a typically subjective basis, and may be delayed in its presentation, taking hours or even days to become symptomatic. Brain trauma is caused by two types of forces to the head/skull; linear and rotational which cause head acceleration, with brain deformation occurring on head acceleration. Linear forces are forces acting in the direction of the head, whereas rotational are angular forces to the head. While both linear and rotational forces are involved in almost every impact to the head, rotational impacts are more serious as they are more likely to cause brain trauma as they warp the white matter in the brain, causing neurons to twist, stretch and shear.

[0008] Microvascular injury is common after brain trauma and may persist for some time, being as visceral as a torn hamstring. Blood-brain barrier dysfunction and damage to the integrity of the blood-brain barrier, that is leakiness, are commonly associated with microvascular injury. This leakiness of the blood-brain barrier occurs even with mild head impacts, and without any reported symptoms that are commonly associated with a diagnosis of concussion.

[0009] Awareness of the risk of repeated brain trauma is increasing, in particular in professional sports, with sporting federations and governing bodies considering changes to game play and team substitution rules. In this context, research into, and diagnosis of, Chronic Traumatic Encephalopathy (CTE), which is a progressive neurodegenerative disease caused by brain trauma and repetitive blows to the head, has increased this awareness yet further.

[0010] CTE may lead to dementia and related physical and cognitive symptoms such as memory problems, a decline in thinking ability, confusion, aggression, depression and changes in personality; all of which may be debilitating and life-changing for those affected. In addition, large epidemiological studies have shown the risk of dementia and other neurodegenerative diseases such as Motor Neurone Disease are up to four times higher in players of contact sports.

[0011] Headbands have been developed to reduce the risk of brain trauma. Prior art headbands, such as that provided in US2014/0331391A1, have focused on reducing the magnitude of impact to the head rather than the brain, mostly by dissipating linear forces. These prior art headbands for protection from impact forces have been too heavy, not in the design style of sporting accessories/equipment, and too thick for good performance in sports, and as a result have not been widely adopted. These prior art headbands have lacked compelling clinical data meaning their adoption has lagged, with use limited to players with either previous injuries or parental pressure or medical reasons to wear a headband.

[0012] It is also important for a headband, for protecting a user's head from impact forces, to securely sit on a user's head, in particular during vigorous exercise. One impact reduction headband was famously worn during a game by UK footballer Wayne Rooney in 2013, and fell off as he headed a ball into goal.

[0013] The present inventor has appreciated the need for a headband which reduces the transmission of rotational impact forces to the head and ultimately the brain, while at the same time still addressing linear impact forces. The inventor has further appreciated the need for a headband which is lighter, thinner, easier to transport, sits more securely on a user's head, and is more suited for sports design and style through custom print design to complement the player's kit.

SUMMARY OF INVENTION

[0014] The invention provides a headband, as defined in the appended independent claim, to which reference should now be made. Preferred or advantageous features of the invention are set out in the dependent sub-claims.

[0015] In a first aspect, the invention provides a headband for protecting a user's head from impact forces. The headband comprises a first external layer and an opposing second external layer; an impact absorbing layer between the first and second external layers; and a slip layer positioned between the absorbing layer and one of the first and second external layers. Upon the headband receiving an impact, the slip layer facilitates relative movement between the impact absorbing layer and the one of the first and second external layers.

[0016] As used herein, the term “slip layer” refers to a layer of low-friction material that facilitates movement between layers adjacent to the slip layer.

[0017] Although the headband is defined as being for protecting a user's “head”, a skilled person would understand that the headband is equally for protecting a user's “skull”, and ultimately, a user's “brain”.

[0018] It should be understood that the impact forces from which the headband protects may be linear and/or rotational impact forces.

[0019] In contrast to prior art headbands, such as that of US2014/0331391A1, the relative movement between the impact absorbing layer and one of the external layers allows for rotational forces to be better dissipated and reduces their transmission. In particular, the slip layer of the headband of the present invention allows for rotational forces to be dissipated by the impact absorbing layer slipping relative to one of the external layers, i.e. the layer directly adjacent a user's head or the layer that receives the impact. This allows for the reduced transmission of rotational forces to the brain.

[0020] Advantageously, this means that unlike the headbands of the prior art, in which protective layers are glued or stitched directly to the external layers, rotational forces may be dissipated by movement of layers relative to one another. In this way, the headband of the present invention may provide significant relative linear impact reduction and significant relative rotational impact reduction.

[0021] It is further noted that, as the headband embodying the present invention does not require glue, it is environmentally friendly and capable of being machine-washed.

[0022] The invention is usable to protect a user's head/skull from impact forces in contact sports, and in any setting where there is an increased risk of brain trauma or falls. As such, the headband embodying the present invention may be used in martial arts, wrestling, in nursing care, and in professions such as construction and policing.

[0023] Preferably, the headband further comprises a second slip layer positioned between the impact absorbing layer and the other of the first and second external layers. Upon the headband receiving the impact, the second slip layer facilitates relative movement between the impact absorbing layer and the other of the first and second external layers.

[0024] Advantageously, the second slip layer allows the impact absorbing layer to slip relative to both the first and second external layers, thereby further improving the rotational force dissipation of the headband upon impact.

[0025] Indeed, as some embodiments of the headband may comprise at least two slip layers, upon an impact force acting on the outside external layer e.g. in a clockwise direction, the outside external layer is accelerated in a clockwise direction. The underlying layers are then accelerated accordingly. As the layers may move relative to one another, energy is dissipated by the movements of the layers relative to one another. The time over which a user's head experiences the force of the impact is increased, reducing the acceleration experienced by the brain.

[0026] Preferably, the first and second external layers are joined at, or near, each circumferential edge.

[0027] More preferably, the first and second external layers may form an envelope for enclosing the impact absorbing layer and the or each slip layer.

[0028] As used herein, the term “circumferential” refers to a direction circumscribing the user's head when the headband is worn by the user. That is, a direction around the head-foot axis, in a horizontal plane if the user is standing. With reference to the headband, the term “circumferential edges” refers to the long edges of the headband, e.g. the top edge and the bottom edge, when the headband is in use.

[0029] Advantageously, this allows for the impact absorbing layer and the or each slip layer to be safely received within the first and second external layers, so that the headband's structural integrity is high, but the impact layer and the or each slip layer may move relative to the external layers.

[0030] In particular, the or each slip layer and the impact absorbing layer may be separate from the first and second external layers, and preferably also separate from one another, so that relative motion of the internal layers relative to the external layers, and one another, is not impeded. As such, the internal layers may be considered to float, or glide, or slide, within the envelope.

[0031] The impact absorbing layer and the or each slip layer may be smaller than the envelope, so that there is a gap between the circumferential edges of the envelope and the circumferential edges of the impact absorbing layer and the or each slip layer.

[0032] The gap may be small so as to minimise the unprotected area of the headband and to reduce the risk of rucking, or wrinkling, or rolling, of the internal layers, while maintaining the ability of the internal layers to slide relative to the external layers and one another.

[0033] In particular the gap may be between about 0.5 mm to 5 mm, or between about 1 mm to 2 mm.

[0034] Preferably, the material of each layer of the headband is elastic so that, after receiving the impact, the layers of the headband are configured to return, substantially, to their original orientation and shape.

[0035] Advantageously, this allows for the headband to be reusable and multi-impact, i.e. for use to be continued after a first impact. This is different to e.g. a helmet in cycling, which is typically configured to resist a single impact.

[0036] Although each layer of the headband has been defined as being elastic, each layer of the headband may alternatively be termed to be moveable, or stretchable, or flexible, so as to describe the property of the layers allowing for reversible deformation upon impact.

[0037] Preferably, the at least one impact absorbing layer comprises a first impact absorbing sub-layer and a second impact absorbing sub-layer.

[0038] Advantageously, separating the impact absorbing layer into two sub-layers may allow for better dissipation of linear impact forces. Additionally, it may allow for the two sub-layers to be made from different material, or to different thicknesses, so as to adapt the absorption properties to the application.

[0039] A thickness of the first impact absorbing sub-layer may differ from a thickness of the second impact absorbing sub-layer. For example, the thickness of the second impact absorbing sub-layer may be twice the thickness of the first impact absorbing sub-layer.

[0040] More preferably, the headband further comprises a third slip layer between the first and second impact absorbing sub-layers, wherein, upon the headband receiving the impact, the third slip layer facilitates relative movement between the first and second impact absorbing sub-layers.

[0041] Advantageously, the slip layer between the first and second impact absorbing sub-layers enables further dissipation of rotational forces by sliding movement of the impact absorbing sub-layers relative to one another.

[0042] Indeed, excluding the external layers, the “active” layers of the headband may comprise six or seven layers (two slip layers, three impact absorbing sub-layers, and one or two further slip layers, e.g. made of polypropylene, between the three impact absorbing sub-layers) to provide improved mechanical and slipping properties to dissipate, and reduce the transmission of, both linear and rotational forces.

[0043] Preferably, the impact absorbing layer comprises at least one further impact absorbing sub-layer.

[0044] More preferably, the headband comprises at least one further slip layer, the or each further slip layer provided between the or each further impact absorbing sub-layer and an adjacent impact absorbing sub-layer. Upon the headband receiving the impact, the or each further slip layer facilitates relative movement between the respective impact absorbing sub-layers.

[0045] In other words, the headband may comprise a further slip layer for each further impact absorbing sub-layer in the impact absorbing layer. Alternatively, the headband may comprise a or multiple further slip layers only between some of the further impact absorbing sub-layers. That is, if there are e.g. three further impact absorbing sub-layers, the headband preferably comprises three further slip layers, such that each further impact absorbing sub-layer is separated from adjacent impact absorbing sub-layers by a further slip layer. Alternatively, if there are e.g. three further impact absorbing sub-layers, the headband may comprise two further slip layers, such that there is no slip layer between some of the further impact absorbing sub-layers.

[0046] A material of the first slip layer and, if present, the second slip layer, may differ from a material of the third slip layer and, if present, the or each further slip layer.

[0047] The third slip layer and, if present, the or each further slip layer, may comprise polypropylene. Advantageously, polypropylene provides structural stability, and therefore

additional impact absorption, but is also sufficiently low friction to act as a slip layer.
[0048] The third and each further slip layer comprising, or being made of, polypropylene may avoid wrinkling or rucking of the layers.
[0049] A thickness of the third slip layer, and if, present, the or each further slip layer, may be about 0.5 mm.
[0050] The first slip layer, and if present, the second slip layer, may comprise a polymer, in particular a woven polymer. The woven polymer may be plain woven. The plain woven polymer may be a plain woven nylon. The plain woven nylon may be a glass reinforced plain woven nylon, in particular 43G plain woven nylon.
[0051] Advantageously, such a woven polymer is a low friction material that facilitates movement of the layers adjacent the or each slip layer relative to one another. Nylon is capable of reducing friction between the other layers of the headband in a wide range of conditions, independently of environmental conditions such as temperature, humidity, etc.
[0052] The or each slip layer may comprise a fluorocarbon finish.
[0053] Advantageously, a fluorocarbon finish, or fluorocarbon coating, on the surface of the slip layer further reduces the friction between the slip layer and the adjacent layers, improving rotational force dissipation due to increased slippage.
[0054] Advantageously, further impact absorbing sub-layers may further improve the dissipation of linear and rotational forces, and allow for better adaptation to specific use cases. Further, the additional slip layers between each impact absorbing sub-layer may improve dissipation of rotational forces yet further.
[0055] Preferably, a thickness of the impact absorbing layer or each impact absorbing sub-layer is between about 1 mm and about 5 mm, more preferably between about 2 mm to about 4 mm, and yet more preferably about 3 mm.
[0056] Preferably, a thickness of the headband is less than 15 mm. More preferably, the thickness of the headband is less than 10 mm. Yet more preferably, the thickness of the headband is about 9.5 mm.
[0057] As used herein, the term “thickness of the headband” refers to the maximum thickness of the headband, whether at or near the circumferential edges of the headband or at or near a central region of the headband. The thickness is with reference to a radial dimension, i.e. a dimension in a direction substantially perpendicular to the head-foot axis.
[0058] Advantageously, a thinner headband is more comfortable to wear, and less obstructive when playing sports, e.g. when heading a ball in football. Due to the superior properties of the headband of the present invention, a thinner headband embodying the present invention may still dissipate rotational forces better than prior art headbands. Further, the headband may be more discrete to wear.
[0059] Preferably, a mass of the headband is less than 100 grams. More preferably, the mass of the headband is less than 80 grams. Yet more preferably, the mass of the headband is about 76 grams.
[0060] Advantageously, a lighter headband is more comfortable to wear, and less obstructive when playing sports, e.g. when heading a ball in football. Due to the superior properties of the headband of the present invention, a lighter headband embodying the present invention may still dissipate rotational forces better than prior art headbands.
[0061] Further, the light weight reduces the user's awareness of the headband while wearing it during game play. This means that “false confidence”, often associated with increased risk taking e.g. when wearing a helmet, is avoided and so the user does not develop a “superhero mentality”.
[0062] The lighter headband may also be more accessible to female users, as a headband puts weight on a user's neck, and women's neck girths are about 30% less than men's. Further, neck strengthening techniques are often not part of standard training, and so the lightweight headband does not require such strengthening techniques to be introduced into a user's training program.
[0063] Preferably, the headband is configured to, in use, cover at least 35% of a user's head. More

preferably, the headband is configured to, in use, cover at least 45% of a user's head. Yet more preferably, the headband is configured to, in use, cover 50% and 55% of a user's head. In some embodiments, the headband may be configured to, in use, cover about 53% of a user's head.

[0064] There is a need to balance the headband's coverage of the user's head with comfort and usability. While a larger coverage increases the area of the user's head which is protected against impact forces, it may also lead to overheating and reduced comfort. As such, the coverage must be focused on areas of the head that most need to be protected, e.g. because the brain is at increased risk of rotational acceleration from an impact, i.e., the back and side of the head, or where the skull offers less natural protection. The inventor has found that covering between about 50% and 55% of a user's head surface area offers a promising trade-off. Covering 50% to 55% of the user's head surface area results in 80% of the sites of likely impact across contact sports to be covered. For example, the top/crown of the head receives only circa 6% of impacts and is the area which creates the lowest rotational forces to the brain, and thus may not require any protection.

[0065] Most preferably, the headband is further configured to, in use, not block any of the user's visual field and/or hearing. This allows for a user's head to be protected, without negatively impacting the user's visual field and/or hearing and/or restraining the user's head movement, which may be essential requirements in sports.

[0066] The outer surface of the headband is preferably substantially smooth. Having a smooth outer surface, combined with a headband covering between about 50% and 55% of a user's head, reduces the number of catch-points. Such catch-points could result in more severe rotational forces on a user's head.

[0067] Preferably, the impact absorbing layer, or each impact absorbing sub-layer, comprises a foam material. More preferably, the foam material is a closed cell foam material. Yet more preferably, the closed cell foam material is a polymer, preferably a blended vinyl/nitrile polymer. Most preferably, the polymer has a density of between about 125 kg per cubic meter and about 175 kg per cubic meter.

[0068] Advantageously, such a foam material is particularly suitable for absorbing, or dissipating, linear and rotational forces to reduce brain trauma. The density of the polymer is selected to provide improved linear and rotational impact absorption. The polymer is selected so as to avoid having to change the nature of sport, e.g. to not affect head-to-ball contact, and to avoid causing additional risk, e.g. a head-to-head contact that would cause additional trauma and injury to another player. As the polymer is lightweight, the additional load placed on the head and neck of the user is limited.

[0069] Additionally, a blended vinyl/nitrile polymer performs consistently across a temperature range of minus 30° C. to 60° C., covering all use cases, and operating environments/locations.

[0070] Further, the polymer may have a maximum 3% water absorption, meaning the headband does not significantly increase in weight in wet weather playing conditions or when a user is sweating heavily, and does not lose its shape and comfortable fit.

[0071] Preferably, the first external layer which, in use, is adjacent the user's head, comprises a fabric. In particular, the fabric may comprise polyamide fibres, preferably nylon fibres. The fabric may further comprise silver microparticles to prevent bacterial growth. The nylon fibres may be hollow.

[0072] More preferably, the fabric is a stretch medical spacer/high tenacity filament fabric with polyester and/or elastane. Most preferably, the fabric has a density between about 200 grams per square metre and about 800 grams per square metre, more preferably between about 200 grams per square metre and about 400 grams per square metre, and in one particular embodiment about 280 grams per square meter.

[0073] Advantageously, a fabric, and more specifically a stretch medical spacer, provides improved airflow adjacent the user's head. Due to the compressibility of the fabric, the comfort of the user is improved due to the stretchability.

[0074] The fabric may further be machine washable, so that there is no deterioration in performance after washing. Further, the fabric is dyeable and dyed and finished under REACH regulations and ISO 9001 quality standards.
[0075] Further, the medical spacer fabric may inherently be antibacterial, hypoallergenic, and sweat-wicking.
[0076] Preferably, the first external layer comprises a gripping surface adjacent the user's head. More preferably, the gripping surface may comprise silicone. Yet more preferably, the gripping surface may comprise a pattern of silicone dots. Alternatively, the gripping surface may comprise a pattern of silicone stripes. The gripping surface may comprise any pattern of silicone, such as indicia, e.g. branding.
[0077] Advantageously, this may prevent the headband from falling off inadvertently, e.g. during head-to-head or head-to-ball contact.
[0078] More preferably, the gripping surface is provided on the first external layer so that in use, it is adjacent at least a portion of the sides and front of the user's head. As the headband may also be very slightly spaced from the user's forehead by the gripping surface, it may advantageously create air flow channels.
[0079] Optionally, the gripping surface may be provided only adjacent at least a portion of the sides and front of the user's head.
[0080] Optionally, the gripping surface may be provided on the first external layer so that in use, it is adjacent at least a portion of the back of the user's head.
[0081] Optionally, the gripping surface may be provided on the first external layer so that in use, it is adjacent at least a portion of each of the sides, a front, and a back of the user's head.
[0082] Preferably, the second external layer which, in use, is furthest from the user's head, comprises a fabric. More preferably, the second external layer comprises a stretchable fabric, which may yet more preferably be a stretchable polyester fabric, or a stretchable nylon. Most preferably, the stretchable polyester fabric has a density of between about 50 grams per square metre and about 200 grams per square metre, more preferably between about 100 grams per square metre and about 200 grams per square metre, and in one particular embodiment about 190 grams per square metre.
[0083] Advantageously, a fabric, and more specifically a stretchable polyester fabric, provides low friction, and allows for improved rotational force dissipation. As the fabric is lightweight, the additional load placed on the head and neck of the user is reduced.
[0084] Further, the fabric may be of any colour to match any team's colours and kit pattern, and may further comprise logos, branding, and advertising. The polyester fabric may be waterproof, abrasion and tear resistant, and may offer UV protection.
[0085] The headband may comprise an anterior portion and a posterior portion. Optionally, the anterior portion and the posterior portion may be joined to each other. Optionally, the headband may circumscribe the head through 360 degrees.
[0086] As used herein, the terms “anterior” and “posterior” have their normal meaning in anatomy.
[0087] It is noted that even though the anterior and posterior portions are referred to as separate portions of the headband, they may each comprise portions of the same layer—for example, the external layers may be continuous layers that form part of both the anterior portion and the posterior portion of the headband, without any clear separation between the anterior and posterior portions.
[0088] As used herein, the term “axial” refers to a direction which is substantially coaxial with the head-foot axis. With reference to the headband, the term “axial edge” refers to the short edges of the headband section or portions, e.g. the edges which are substantially perpendicular to the circumferential edges.
[0089] Optionally, the anterior portion may comprise a different number of layers than the posterior portion.
[0090] Advantageously, separate anterior and posterior portions of the headband allow for the

number of layers, the type and material of layers, the size and thickness of layers, and the other features of the layers to differ between the anterior and posterior portions of the headband, so as to account for differences in likelihood of impact, severity of impact, brain trauma susceptibility, and the like of different parts of the head.

[0091] In particular, the posterior portion may be wider than the anterior portion. As used herein, the width of the headband refers to a dimension of the headband in an axial direction, i.e. a direction which is substantially coaxial to the head-foot axis.

[0092] The wider posterior portion may provide improved occipital protection, i.e. from falling onto the back of head or from a blunt force to the back of the head. Further, the wider portion also allows for a space for advertisement/sponsorship.

[0093] Optionally, the posterior portion may comprise fewer layers than the anterior portion.

[0094] The posterior portion may comprise the first external layer; the second external layer; the slip layer; the second slip layer; and an impact absorbing layer comprising three impact absorbing sub-layers and one further slip layer; and the anterior portion may comprise: the first external layer; the second external layer; the slip layer; the second slip layer; and an impact absorbing layer comprising three impact absorbing sub-layers and two further slip layer.

[0095] The anterior and posterior portions may be joined by seams. Each seam may be narrow, i.e. between about 0.5 mm and about 2 mm, or between about 1 mm and 1.5 mm.

[0096] The width of the seams refers to a dimension of the seams in a substantially circumferential direction.

[0097] The seams may be angled relative to the head-foot axis.

[0098] The external layers may be longer, in a circumferential direction, than the impact absorbing layer and the or each slip layers, so that there is a gap between the axial edges of the impact absorbing layer and the or each slip layers and the seams.

[0099] Indeed, upon an impact force acting on the outside external layer e.g. in a clockwise direction, the outside external layer is accelerated in a clockwise direction. The underlying layers are then accelerated accordingly. However, as the circumferential clearance, or gap, between the internal layer(s) and the external layers is relatively small and the internal layer(s) substantially abut(s) any axial ends of the envelope(s), i.e. the seams, the accelerated internal layer(s) may rebound off the axial ends.

[0100] Upon rebound, the impact absorbing layer may slip relative to the outside external layer in a counter-clockwise direction, which may result in the inside external layer slipping relative to the impact absorbing layer in a clockwise direction upon (repeated) rebound of the impact absorbing layer. This “zig-zag” deflection of different layers of the headband relative to one another may further increase rotational force dissipation.

[0101] In other words, the rebounding internal layer(s) may result in acceleration of adjacent layers in opposing directions, as the headband oscillates circumferentially. As the movement of the external and internal layers increases the time over which forces from an impact are experienced by a user's head, the acceleration caused by the impact on the brain is reduced, so as to prevent or reduce brain trauma.

[0102] Alternatively, or in addition, to rebounding off the axial ends, the “zig-zag” movement in opposing directions may also, or instead, be caused by a restraint limiting movement of layers relative to one another to a specific distance, and upon reaching the limit, resulting in an opposed movement in the opposite direction. This “zig-zag” movement in particular reduces transmission of rotational forces to a user's head/brain.

[0103] As the materials and sizing of the headband are preferably selected such that a user must stretch the headband to allow the user to put the headband on their head, the headband fits snugly to the user's head when in use. This causes the user to not notice the headband while wearing it during game play. This means that “false confidence”, often associated with increased risk taking e.g. when wearing a helmet, is avoided and the user does not develop a “superhero mentality”.

[0104] Preferably, the seams are configured to allow the headband to fold flat.
[0105] Advantageously, the flat-folded headband may be more easily transported and is less likely to be damaged when being transported. The flat-folded headband is also more easily washable. The headband may be provided with a netted washbag for washing in a washing machine, packaging and storage.
[0106] More preferably, the anterior and posterior portions have substantially the same circumferential length. This may allow the headband to fold completely flat.
[0107] Portions of the anterior portion and the posterior portion may be configured to overlap.
[0108] The first impact absorbing sub-layer of the anterior portion and the second impact absorbing sub-layer of the posterior portion may be configured to overlap.
[0109] The second impact absorbing sub-layer of the anterior portion and the first impact absorbing sub-layer of the posterior portion may be configured to overlap.
[0110] Overlapping may allow for the headband to protect the user's head around 360 degrees, without any (axial) gap. Overlapping may provide a “brick effect”, which may improve impact absorption.
[0111] At least one of the impact absorbing sub-layers of the anterior portion may extend beyond at least one of the other impact absorbing sub-layers of the anterior portion.
[0112] At least one of the impact absorbing sub-layers of the posterior portion may extend beyond at least one of the other impact absorbing sub-layers of the posterior portion
[0113] As used herein, the term “extend beyond” when applied to sub-layers refers to one sub-layer being longer, in a circumferential direction, than another sub-layer, and thereby protruding, in the circumferential direction, from the “shorter” sub-layer it extends beyond.
[0114] The headband may comprise at least one restraint configured to limit movement of one of the layers relative to another one of the layers. The restraint may be arranged between one impact absorbing sub-layer and an adjacent one of the impact absorbing sub-layers, so as to restrain, or limit, movement between the one, and the adjacent one, of the impact absorbing sub-layers.
[0115] Movement may appropriately be limited by the restraint to about 10 to 50 mm, or about 20 to 40 mm, or about 30 mm, or about 25 mm, or about 20 mm.
[0116] Optionally, the restraint may be, at least partially, elastic.
[0117] Optionally, each of the anterior portion and the posterior portion may comprise at least one restraint.
[0118] Optionally, a restraint of the anterior portion may limit movement more (i.e. to a smaller distance) than a restraint of the posterior portion, or vice versa. This may allow for the headband to be better adapted to specific expected impacts to the anterior portion and the posterior portion.
[0119] In particular, the anterior portion may comprise a restraint which separates an outer impact absorbing sub-layer and a slip layer from inner impact absorbing sub-layers and a further slip layer. In particular, the posterior portion may comprise a restraint which separates an outer impact absorbing sub-layer and a slip layer from inner impact absorbing sub-layers.
[0120] Optionally, each of the anterior portion and the posterior portion comprises only one restraint.
[0121] Optionally, the or each restraint is attached to the layers by stitching (i.e. by a seam).
[0122] Optionally, the or each restraint is attached to a centre of the respective portion. This is particularly advantageous if there is only one restraint per portion. It is noted that the centre of a portion may refer to a centre in a longitudinal direction of the portion, or in a transverse direction of the portion, or preferably, in both a longitudinal and a transverse direction.
[0123] The restraint may be a tape. Optionally, the tape may be attached to at least two layers of the headband. The tape may be a polyester tape.
[0124] The restraint may also prevent the layers from permanently moving out of alignment, which could reduce the protection of the headband from linear and rotational forces. For example, if the restraint is not present, and a headband is deformed excessively, e.g. by a headband that is too

small being worn, or the headband being placed at the bottom of a full sports bag, for an extended period, one or more of the layers may be misaligned permanently from the other layers. The restraint, by limiting movement of the layers relative to one another, may prevent such misalignment, thus increasing longevity and effectiveness of the headband.

[0125] The headband may be provided in a range of head sizes. The headband may be machine washable. The headband may be sufficiently durable for repeated use, e.g. over the course of at least one year, or sport's season. The headband may be soft, comfortable, breathable, cooling, sweat-wicking and may have antibacterial properties.

[0126] The headband may embrace a sport team's colours and graphics, allowing for customisable team kit design. Consideration has been given to the grip of the headband to the head during games and training, with a stylish inner non-slip silicone coating. Thought has also been given to the heading of a football, and to ensure the headband creates no competitive advantage or disadvantage around ball control.

[0127] The headband may comprise indicia configured to indicate to a user the correct orientation of the headband. This may prevent the user from wearing the headband upside down, and may aid the user in putting on the headband so that it provides optimal protection.

[0128] An inner lining of the headband may contain guidance on brain injury symptoms. The inner lining may also include legal disclaimers, and wash and care guidance.

[0129] The headband may also comprise an identification tag with a unique product number. The tag allows for product tracing and registering ownership of the product.

[0130] The materials of each of the layers are chosen so that the headband is machine washable and quick drying, which benefits both game play and in laundry care.

[0131] According to a second aspect of the present invention, there is provided a helmet comprising a headband according to the first aspect.

[0132] The helmet may comprise at least one flexible support element configured to, in use, extend across a top or crown of a user's head for holding the helmet in place on the user's head.

[0133] The helmet may comprise at least two flexible support elements, one running from a front of the helmet to a back of the helmet, and one running from one side of the helmet to the other side of the helmet.

[0134] Additionally or alternatively, the at least one flexible support element may comprise webbing.

[0135] The headband may be removably attached to the helmet. For example, the headband may be removably attached to the helmet using a hook and loop fastener. Alternatively, or additionally, the headband may be removably attached to the helmet using a zipper.

[0136] Alternatively, the headband may be attached to the helmet in a non-detachable manner.

[0137] For example, the headband may be attached to the helmet by at least one restraint. The restraint may have the same features as the restraint of the headband of the first aspect. Indeed, in some examples, the at least one restraint of the headband may also attach the headband to the helmet.

[0138] Optionally, the at least one restraint may be two restraints, or three restraints, or four restraints, or five restraints. Four restraints may be preferable. If there is more than one restraint, the restraints may be distributed evenly around a circumference of the headband. For example, if there are four restraints, the restraints may be arranged such that one restraint connects the headband on either side of the helmet, one restraint connects the headband at a front of the helmet, and one restraint connects the headband at a back of the helmet.

[0139] The at least one restraint attaching the headband to the helmet may limit movement between the headband, or some layers of the headband, and the helmet to about 10 to 50 mm, or about 20 to 40 mm, or about 30 mm, or about 25 mm, or about 20 mm.

[0140] Optionally, the restraint may be, at least partially, elastic.

[0141] Optionally, the or each restraint is attached to the helmet and to the headband by stitching

(i.e. by a seam).
[0142] The restraint may be a tape. The tape may be a polyester tape.
[0143] Alternatively, the headband may be attached to the helmet using an adhesive.
[0144] Further alternatively, the headband may be attached to the helmet by stitching.
[0145] The headband may be attached to the helmet only along its periphery.
[0146] According to a third aspect of the present invention, there is provided a helmet comprising a headband for protecting a user's head from impact forces, wherein the helmet forms a first external layer of the headband, and the headband comprises: an opposing second external layer; an impact absorbing layer between the first and second external layers; and a slip layer positioned between the impact absorbing layer and one of the first and second external layers, wherein, upon the headband receiving an impact, the slip layer facilitates relative movement between the impact absorbing layer and the one of the first and second external layers.
[0147] Any of the features set out in relation to the headband of the first aspect may be applied to the helmet of the third aspect. In particular, the helmet of the third aspect may comprise additional layers, additional features such as the restraints, and the layers of the helmet of the third aspect may be made of the materials set out with respect to the headband of the first aspect.
[0148] In the helmet of the third aspect, a rim of the opposing second external layer may be attached to an interior of the helmet creating a pouch in which the internal layers are placed.
[0149] The helmet may further comprise at least one restraint for attaching at least one of the internal layers to the helmet. The at least one restraint may be the same restraint as the restraint attaching the internal layers to one another.
[0150] Optionally, the at least one restraint may be two restraints, or three restraints, or four restraints, or five restraints. Four restraints may be preferable. If there is more than one restraint, the restraints may be distributed evenly around a circumference of the headband. For example, if there are four restraints, the restraints may be arranged such that one restraint connects the headband on either side of the helmet, one restraint connects the headband at a front of the helmet, and one restraint connects the headband at a back of the helmet.
[0151] The at least one restraint attaching at least one of the internal layers to the helmet may limit movement between the helmet and the at least one of the internal layers to about 10 to 50 mm, or about 20 to 40 mm, or about 30 mm, or about 25 mm, or about 20 mm.
[0152] Optionally, the restraint may be, at least partially, elastic.
[0153] Optionally, the or each restraint is attached to the helmet and to the (at least one of the internal layers of the) headband by stitching (i.e. by a seam).
[0154] The restraint may be a tape. Optionally, the tape may be attached to at least two layers of the headband. The tape may be a polyester tape.
[0155] In other words, the helmet of the third aspect, and the headband of the first aspect, differ only in that the headband of the first aspect comprises a first external layer (the layer furthest from the head in use), whereas in the helmet of the third aspect, the first external layer is a shell, or a liner, of the helmet.
[0156] In the helmet of the second or third aspect, when the headband comprises an anterior portion and a posterior portion, the anterior portion and the posterior portion may not be directly attached to one another. That is, the anterior portion and the posterior portion may be independently attached to the helmet, but not to one another. The posterior and anterior portions may still, together, form a headband.
[0157] As such, in a fourth aspect, the disclosure provides a headgear for protecting a user's head from impact forces, comprising: a first external layer and an opposing second external layer; an impact absorbing layer between the first and second external layers; and a slip layer positioned between the impact absorbing layer and one of the first and second external layers, wherein, upon the headband receiving an impact, the slip layer facilitates relative movement between the impact absorbing layer and the one of the first and second external layers. The headgear of the fourth

aspect may, for example, be a headband, or it may be a helmet.
[0158] It should be appreciated that particular combinations of the various features described and defined in any aspects of the invention may be implemented and/or supplied and/or used independently.

Description

DESCRIPTION OF SPECIFIC EMBODIMENTS OF THE INVENTION
[0159] Specific embodiments of the invention will now be described with reference to the figures, in which:
[0160] FIG. **1***a* is a schematic cross-sectional view of a headband embodying the present invention;
[0161] FIG. **1***b* is a schematic cross-sectional view of another headband embodying the present invention;
[0162] FIG. **2** is a schematic cross-sectional view of another headband embodying the present invention;
[0163] FIG. **3** is a schematic cross-sectional view of another headband embodying the present invention;
[0164] FIGS. **4***a* and **4***b* are schematic cross-sectional views of the relative movement between layers of a headband embodying the present invention upon receiving an impact;
[0165] FIG. **5** is a front view of a headband embodying the present invention;
[0166] FIG. **6** is a perspective front view of the headband of FIG. **5**;
[0167] FIG. **7** is a back view of the headband of FIGS. **5** and **6**;
[0168] FIG. **8** is a perspective back view of the headband of FIGS. **5**, **6**, and **7**;
[0169] FIG. **9** is a side-on view of the headband of FIGS. **5** to **8**;
[0170] FIG. **10** is a side-on view of the headband of FIGS. **5** to **9** worn by a user;
[0171] FIGS. **11** to **13** are front, back, and side-on views of the internal layers of the headband of FIGS. **5** to **10**;
[0172] FIG. **14** is a back view of the internal layers of a posterior portion of the headband of FIGS. **5** to **13**;
[0173] FIG. **15** is a side-on view of the internal layers of the headband of FIGS. **5** to **14** worn by a user;
[0174] FIG. **16** is a front view of the headband a further headband embodying the present invention;
[0175] FIG. **17** is a perspective front view of portions of the headband of FIG. **16**;
[0176] FIG. **18** is a schematic cross-sectional view of a posterior portion of the headband of FIGS. **16** and **17**;
[0177] FIG. **19** is a schematic cross-sectional view of an anterior portion of the headband of FIGS. **16**, **17**, and **18**;
[0178] FIG. **20** is a perspective back view of portions of the headband of FIGS. **16** to **19**;
[0179] FIG. **21** shows two side views, and a corresponding top view of the internal layers, of the headband of FIGS. **16** to **20**;
[0180] FIG. **22** shows a perspective back view of the internal layers of the headband of FIGS. **16** to **21**;
[0181] FIGS. **23**A and **23**B show top views of the headband, and the internal layers of the headband, of FIGS. **16** to **22**;
[0182] FIG. **24** shows a further schematic cross-sectional view of the posterior portion of the headband of FIGS. **16** to **23**B;
[0183] FIG. **25** shows a further schematic cross-sectional view of the anterior portion of the headband of FIGS. **16** to **24**;

[0184] FIG. **26** shows a schematic cross-sectional view of an exemplary helmet of the disclosure;
[0185] FIG. **27** shows a schematic cross-sectional view of another exemplary helmet of the disclosure; and
[0186] FIG. **28** shows a schematic cross-sectional view of yet another exemplary helmet of the disclosure.

SPECIFIC DESCRIPTION

[0187] FIG. **1***a* illustrates the layers making up a headband **100***a* embodying the present invention. The headband **100***a* comprises a first external layer **102**, a slip layer **104***a*, an impact absorbing layer **106** and a second external layers **108**.

[0188] It is noted that the first and second layers **102**, **108** may differ, and that the layer shown at the top of FIG. **1***a* may be the layer of the headband **100***a* which in use is in contact with the head, or the layer which in use is furthest from the head.

[0189] The slip layer **104***a* is made from a plain weaved, 43G nylon with a fluorocarbon finish, and provides a low friction layer between the first external layer **102** and the impact absorbing layer **106**.

[0190] The first and second layers **102**, **108** are longer, in a circumferential direction, than the slip layer **104***a* and the impact absorbing layer **106** so as to produce a gap. This gap allows the internal layers (which refers to the slip layer **104***a* and the impact absorbing layer **106**) to move relative to one of the external layers **102**, **108**.

[0191] FIG. **1***b* illustrates the layers making up another headband **100***b* embodying the present invention, comprising the layers of headband **100***a* of FIG. **1***a*, and further a second slip layer **104***b* between the impact absorbing layer **106** and the other of the external layers **108**, so that there is a slip layer between the impact absorbing layer **106** and each of the external layers **102**, **108**. As such, the slip layers **104***a*, **104***b* facilitate movement of the impact absorbing layer **106** relative to the first and second external layers **102**, **108**.

[0192] FIG. **2** illustrates the layers making up a further headband **200** embodying the present invention, comprising the layers of headband **100***b* of FIG. **1***b*. In the headband **200**, the impact absorbing layer **106** comprises a first impact absorbing sub-layer **110***a*, a second impact absorbing sub-layer **110***b*, and a third slip layer **104***c* between the first and second impact absorbing sub-layers **110***a*, **110***b*, which facilitates movement of the first and second impact absorbing sub-layers **110***a*, **110***b* relative to one another.

[0193] FIG. **3** illustrates the layers making up a further headband **300** embodying the present invention, comprising the layers of headband **200** of FIG. **2**. In the headband **300**, the impact absorbing layer **106** further comprises a third impact absorbing sub-layer **110***c*, and a fourth slip layer **104***d* between the second and third impact absorbing sub-layers **110***b*, **110***c*, which facilitates movement of the second and third impact absorbing sub-layers **110***b*, **110***c* relative to one another.

[0194] FIGS. **4***a* and **4***b* illustrate the way in which the layers of a headband **200**, as illustrated in FIG. **2**, move relative to one another so as to dissipate rotational forces caused by an impact. In FIG. **4***a*, the headband **200** is shown before impact by a ball **400**.

[0195] In FIG. **4***b*, after the impact, the layers and sub-layers of the headband **200**, which are each separated by a slip layer **104***a*, **104***b*, **104***b*, are shown as moving in opposing directions relative to adjacent layers. This movement in opposing directions may be caused by rebound of the (sub-layers of the) impact absorbing layer **106** rebounding off the axial ends of the external layers **102**, **108** (i.e. the envelope) of the headband **200**. In other words, the internal layers of the headband **200** oscillate. This relative movement of the layers requires energy, leading to dissipation of rotational forces, and increasing the time over which impact forces, and corresponding acceleration, is experienced by the brain.

[0196] As set out above, alternatively, or in addition, to rebounding off the axial ends, the “zig-zag” movement in opposing directions may also, or instead, be caused by a restraint limiting relative movement of different layers to a specific distance, which upon reaching the limit, causes an opposed movement in the opposite direction.

[0197] After the impact forces have been dissipated, the layers of the headband **200**, due to their elasticity, move in the opposing directions to those shown in FIG. **4***b*, so as to return, substantially, to their original state (e.g. orientation and shape) as shown in FIG. **4***a*.

[0198] As shown in FIGS. **5** to **10**, the headband **200** comprises an anterior portion **500** and a posterior portion **502**. The anterior portion **500** and the posterior portion **502** are joined to one another along their short axial edges, that is the edges which, when the headband **200** is in use (e.g. when it is worn on a user's head), are substantially coaxial with the user's head-foot axis. The anterior and posterior portions **500**, **502** are joined at seams **504**.

[0199] Each of the anterior and posterior portion **500**, **502** are made up of first and second external layers **102**, **108** which are joined to one another along circumferential edges **506**. The anterior portion **500** is in the form of a narrow headband, whereas the posterior portion **502** is wider than the anterior portion **500** and has two bulging portions **600** configured to cover an occipital portion of a head when a user **1000** wears the headband **200**. As shown in FIG. **10**, the headband **200** is shaped such that it does not obscure hearing or a peripheral vision of the user **1000**.

[0200] The maximum thickness of the headband **200**, in this example, is 8 mm.

[0201] The seams **504** are configured such that, when the headband **200** is worn by the user **1000**, the seams **504** cover a portion adjacent and above a posterior end of the user's **1000** ears, as shown in FIG. **10**. It has been found that this portion of a user's **1000** head is least likely to suffer an impact force.

[0202] The seams allow for the headband **200** to be folded flat, for easier washing, storage, and transportation.

[0203] In FIGS. **11** to **15**, the circumferential edges **506** and the axial edges of the external layers **102**, **108** are shown as dashed lines. The external layers **102**, **108** are joined along the circumferential edges **506** and the axial edges **1300** to form an envelope for receiving, or holding, the internal layers **1100**, **1102**.

[0204] The internal layers **1100** of the anterior portion and the internal layers **1102** of the posterior portion are smaller than the envelope, and wholly contained within the envelope. The term "internal layers", or active layers, refers to the or each slip layer **104***a*, **104***b* and the impact absorbing layer **106** (including the or each impact absorbing sub-layer **110***a*, **110***b*, **110***c* and the or each slip layer **104***c* and **104***d*).

[0205] As the internal layers **1100**, **1102** are smaller than the envelope, small circumferential gaps **1104** and small axial gaps **1302** are formed between the periphery of the inner layers **1100**, **1102** and the joined edges of the envelope. These gaps are no more than 2 mm wide so as to maximise the protected surface area of the user's **1000** head, while allowing relative movement between the internal layers **1100**, **1102** and between the internal layers **1100**, **1102** and the envelope, so as to dissipate rotational forces, without causing rucking or rolling.

[0206] The or each impact absorbing (sub-)layer is formed of 3 mm grey vinyl nitrile foam. A particularly suitable foam is S3VN10a available from Alanto™.

[0207] This polymer (and similar suitable polymers) has been tested for linear impact reduction, and certified against the following standards: Equestrian standards-European Levels 1 & 3 to EN13158 2009, BETA levels 1 & 3 2009, & BS 7971-4 levels 1, 2 & 3; Motorcycle standards European Level 1 EN1621; and Blunt Trauma Standards BS7971-8 & BS7971-levels 1, 2 & 3.

[0208] The grey vinyl nitrile foam performs consistently across a temperature range of minus 30° C. to 60° C. The polymer has a maximum 3% water absorption.

[0209] The headband **200** is shaped so as to fit both male and female user's **1000**, being configured to take into consideration differences in positioning and sizing of headbands **100**, and to take account of different hair styles. That is, the headband **200**, between the bulging portions **600** configured to cover an occipital portion of a head, comprises a recess **1400** for receiving e.g. a ponytail.

[0210] The headband **200** is designed for games rule compliance of soft padded protection and is designed not to be injury causing. As such, headband **200** is configured to comply with, for example, FIFA rule **4**.
[0211] A further headband **1600** embodying the present invention is shown in FIGS. **16** to **23**B. The headband **1600** does not comprise seams, so as to provide protection circumscribing a user's head 360 degrees. Instead, as described below, different impact absorbing sublayers overlap at different circumferential positions so as to create a “brick effect”.
[0212] The general shape of the headband **1600** is similar to that of headband **200**, having an anterior portion **1602** and a posterior portion **1604**, wherein the anterior portion **1602** is in the form of a narrow headband, and the posterior portion **1604** is wider than the anterior portion **1602** and has two bulging portions configured to cover an occipital portion of a head when a user wears the headband **1600**.
[0213] FIGS. **17** and **20** show an inner impact absorbing sub-layer **1700** of the anterior portion **1602** of the headband **1600**, and an outer impact absorbing sub-layer **1702** of the posterior portion **1604** of the headband **1600**. The inner and outer impact absorbing sub-layers **1700**, **1702** overlap in two overlap portions **1704**. As the impact absorbing sub-layers **1700**, **1702** of the anterior and posterior portions **1602**, **1604** overlap, the headband **1600** circumscribes a user's head through 360 degrees.
[0214] FIG. **18** shows a schematic **1800** of the layers of the posterior portion **1604** of the headband **1600** having, from outside (furthest from the head, in use) to inside (closest to the head, in use): an external layer **1802**, an outer slip layer **1804***a* (e.g. plain woven nylon), an outer impact absorbing sub-layer **1702**, a third slip layer **1808** (e.g. polypropylene), an inner impact absorbing sub-layers **1700**, **1806***c* which is twice the thickness of outer impact absorbing sub-layer **1702**, an inner slip layer **1804***b* (e.g. plain woven nylon), and an inner external layer **1810**. The outer slip layer **1804***a* and the inner slip layer **1804***b* may be made of the same material (e.g. woven nylon), whereas the third slip layer **1808** may be made of a different material (e.g. polypropylene).
[0215] FIG. **19** shows a schematic **1900** of the layers of the anterior portion **1602** of the headband **1600** having the same layers as the schematic **1800** of the layers of the posterior portion **1604**, and an additional fourth slip layer **1908** (e.g. polypropylene) in the middle of the two impact absorbing sub-layers **1700** and **1806***c* making up the impact absorption sub-layer which is twice the thickness of the outer impact absorbing sub-layer **1702**. As such, in this embodiment, the anterior portion **1602** comprises one more layer (the additional fourth slip layer **1908**) than the posterior portion **1604**. The additional fourth slip layer **1908** may be made of the same material as the third slip layer **1808**, e.g. polypropylene.
[0216] As shown in FIG. **21**, the outer slip layer **1804***a*, the outer impact absorbing sub-layer **1702**, and the third slip layer **1808** of the posterior portion **1604** extend beyond the inner impact absorbing sub-layers **1700**, **1806***c*. The slip layer **1804***a*, the outer impact absorbing sub-layer **1702**, and the third slip layer **1808** of the posterior portion **1604** contact with the equivalent layers of the anterior portion **1602** at a first circumferential position **2106**.
[0217] The inner impact absorbing sub-layers **1700**, **1806***c* and the inner slip layer **1804***b* of the anterior portion **1602**, extend beyond the slip layer **1804***a*, the outer impact absorbing sub-layer **1702**, and the third slip layer **1808** of the anterior portion. At a different, second circumferential position **2104** to the first circumferential position **2106**, the inner impact absorbing sub-layers **1700**, **1806***c* and the inner slip layer **1804***b* of the anterior portion **1602** contact with the equivalent layers of the posterior portion **1604**.
[0218] Different layers of the anterior portion **1602** and posterior portion **1604** overlapping, and connecting with equivalent layers of the other portion at different circumferential positions **2104**, **2106**, may provide a “brick effect”, so that there is no radial line of weakness. The overlapping at different circumferential positons **2104**, **2106** may also improve sliding of layers to other layers.
[0219] FIG. **22** shows the internal layers of the anterior and posterior portions **1602**, **1604**,

including the additional slip layer **1908**, e.g. of polypropylene, between the inner impact absorbing layers **1806***c*, **1700**. As shown, the inner impact absorbing sub-layers **1700**, **1806***c* of the anterior portion **1602** extend beyond the outer impact absorbing layer **1702** so as to contact the inner impact absorbing layers **1700**, **1806***c* of the posterior portion **1604** at the first circumferential position **2104**.

[0220] The outer impact absorbing layer **1702** of the posterior portion **1604** extends beyond the inner impact absorbing sub-layer **1700**, **1806***c* so as to contact the outer impact absorbing layer **1702** of the anterior portion at the second circumferential position **2106**.

[0221] FIG. **23**A shows a top view of the headband **1600**, and FIG. **23**B shows a top view of the internal layers **2300** of the headband **1600**.

[0222] The headband **1600** may be substantially the same thickness around the entire circumference. The thickness may be about 9.5 mm. The headband **1600** may weigh about 76 grams. In use, the headband **1600** may cover about 52 or 53% of a user's head.

[0223] The slip layers **1804***a* and **1804***b* are made from a plain weaved, 43G nylon with a fluorocarbon finish.

[0224] The impact absorbing sublayers **1702**, **1806***c*, **1700** are made from grey vinyl nitrile foam, and a particularly suitable foam is S3VN10a available from Alanto™. The impact absorbing sublayer **1702** is about 3 mm thick, and the impact absorbing sublayer **1806***c*, **1700** is about 6 mm thick.

[0225] The external layer **1802** is made of a stretchable polyester and/or lycra fabric and the other external layer **1810** is made of a medical spacer material comprising e.g. hollow nylon fibres.

[0226] As shown in FIG. **24**, the headband **1600** comprises a restraint **2400** in the shape of a polyester tape in the posterior portion **1604**. The tape may be 50 mm long and may be attached to the third slip layer **1808** and the inner impact absorbing sub-layer **1806***c* so as to restrain movement of the outer impact absorbing sub-layer **1702** and the third slip layer **1808** relative to the inner impact absorbing sub-layers **1806***c*, **1700**.

[0227] As shown in FIG. **25**, the headband **1600** comprises a further restraint **2500** in the shape of a polyester tape in the anterior portion **1602**. The tape may be 50 mm long and may be attached to third slip layer **1808** and the inner impact absorbing sub-layer **1806***c* so as to restrain movement of the outer impact absorbing sub-layer **1702** and the third slip layer **1808** relative to the inner impact absorbing sub-layers **1806***c*, **1700** and the additional fourth slip layer **1908**.

[0228] The restraints **2400**, **2500** may be lightweight polyester tape having a length of 50 mm, with about 10 mm attached to each layer and 30 mm usable to allow movement of the layers relative to one another. As such, in this embodiment, relative movement of the layers may be limited to about 30 mm in either direction around the circumference.

[0229] As discussed above, the restraints **2400**, **2500** limit the movement of the layers relative to one another, i.e. how far they may rotate/move relative to one another, and they may also prevent free spinning of the layers. This may allow for the integrity and the shape of the headband **1600** to be maintained when the headband **1600** is washed or crumpled into a sports bag etc.

[0230] The restraint also supports, or causes, the “zig-zag” movement of layers relative to one another. Upon an impact force acting on the outside external layer e.g. in a clockwise direction (to the right) in FIG. **24**, the outside external layer is accelerated in a clockwise direction. The underlying layers are accelerated accordingly. In the case of the posterior portion of FIG. **24**, the outer impact absorbing sub-layer **1702** and the third slip layer **1808** are accelerate in a clockwise direction until the restraint **2400** is at its limit, or “full stretch” (about 25 to 30 mm from full stretch in the opposite direction).

[0231] At full stretch, the inner impact absorbing sub-layers **1806***c*, **1700** will be accelerated in a clockwise direction, while the tension of the restraint **2400** will cause the outer impact absorbing sub-layer **1702** and the third slip layer **1808** to move in the anti-clockwise direction, thus causing a reciprocating, or “zig-zag”, movement, as the “rebounding”, or change in direction of movement,

caused by elasticity of the restraint **2400** \may occur repeatedly depending on the linear and rotational impact forces.
[0232] The headband according to the further embodiment of FIGS. **16** to **25** has been assessed to study protection in head-to-ground and head-to-head impacts. To test performance in a head-to-ground impacts, which can be considered the worst-case scenario, a test specimen was impacted with a solid surface without the headband (naked head) and with the headband.
[0233] As is shown in Table 1, based on laboratory testing, the headband may lower the peak linear acceleration of the head by an average (taken over a series of nine separate tests) of 41% on each head-to-ground impact, and peak angular (rotational) acceleration of the head by an average of 27%.
[0234] The headband also increased the impact duration, indicating that the impact was dampened by increasing the duration over which the impact was dissipated.
[0235] This suggests that the headband **1600** reduces linear and rotational forces to the skull; it may therefore reduce the likelihood of concussion/mild traumatic brain injury from single hit(s), and also may reduce the impact from multiple minor/sub-concussive hits to the head which transmit rotational acceleration and deceleration forces to the brain.
TABLE-US-00001 TABLE 1 Results of head-to-ground impact testing. Peak angular (rotational) Peak linear acceleration/G acceleration/rad/s.sup.2 Impact duration/ms Standard Standard Standard Average Deviation Average Deviation Average Deviation Naked head 133.7 3.4 4,798.4 241.8 14.1 0.2 Headband 79.3 3.5 3,510.2 128.8 17.4 0.2
[0236] As set out above, the relative movement, and flexibility, of the layers of the headband **1600** may allowed for impact forces to be dampened. As the layers stretch and move relative to one another, this dampens the impact and reduction forces experienced by the user.
[0237] To assess head-to-head impacts, the Virginia Tech Soccer STAR scoring and test methodology was used. According to the results as shown in Table 2, use of the headband may lower the risk of concussion by 72%.
[0238] The reduction in risk of concussion results from the headband lowering the peak linear acceleration of the head by up to 65% (at a speed of 2 m/s) on each head-to-head impact, e.g. collision or tackle, and lowers the peak angular (rotational) acceleration of the head by up to 61% (at a speed of 2 m/s) on each head-to-head impact.
TABLE-US-00002 TABLE 2 Results of head-to-head impact testing according to the Virginia Tech Soccer STAR scoring and test methodology. Reduction angular Reduction Head band Bare head (rotational) Head band Bare head linear Peak Angular average acceleration Peak Linear average Linear acceleration (rotational) (rotational) achieved by Head Speed Acceleration Acceleration achieved by Acceleration Acceleration headband Area m/s (g) (g) headband (rad/s/s) (rad/s/s) (rad/s/s) Back 2 21.0 57.6 64% 1,613.79 3,938.70 59% 3 47.1 101.8 54% 3,222.67 6,695.34 52% 4 91.1 153.4 41% 6,093.88 10,005.76 39% Side 2 20.8 60.4 65% 2,107.03 5,447.70 61% 3 56.1 102.3 45% 5,736.28 8,830.25 35% 4 92.0 154.3 40% 9,113.43 12,737.34 28%
[0239] The above results show that by wearing the headband, a user may mitigate against a rare one-off hit that might trigger a career or life changing concussion. Additionally, by wearing the headband consistently, the accumulated burden of sub-clinical brain injury may be mitigated. This in turn may reduce the risk of reducing cognitive reserve for one-off hits and the risk of triggering longer-term neurodegenerative risks.
[0240] It is noted that the experimentally determined reductions in linear and angular acceleration of the head are exemplary only and do not limit the invention to any particular reduction.
[0241] FIG. **26** shows a schematic cross-sectional view of a helmet **2600** comprising an external helmet shell **2602**. Attached to the helmet **2600** is a headband **200** according to the above disclosure. Even though the headband **200** is shown as being attached to the shell **2602** of the helmet **2600**, it may be attached to a liner, such as a fabric, of the helmet **2600**.
[0242] To keep the headband **200** and helmet **2600** in place on a user's head, the helmet **2600**

further comprises at least one flexible support element **2604** configured to stretch across the crown of a user's head. The headband **200** is attached to the helmet **2600** by adhesive.
[0243] FIG. **27** shows a schematic cross-sectional view of another example helmet **2700** comprising a shell **2602**. The shell **2602** forms an outer external layer of a "headband" **2702**. The headband **2702** comprises, from the outer external layer (i.e. shell **2602**, or a liner of the helmet **2700**) to an inner external layer **108**: a first slip layer **104**, a first impact-absorbing sub-layer **110***a*, an intermediate slip layer **104***c*, a second impact-absorbing sub-layer **110***b*, and a second slip layer **104***b*.
[0244] The headband **2702** layers are maintained in their position by the inner external layer **108** being extended to attach to the shell **2602** or a liner of the helmet **2700**. This may be achieved by stitching the inner external layer **108** to the remaining helmet so as to create a pouch, or using adhesive.
[0245] FIG. **28** shows a schematic cross-sectional view of another example helmet **2800** which is identical to helmet **2700**, except that the layers of the "headband" **2702** are attached to the outer external layer **2602**, i.e. the shell **2602** or liner of the helmet **2800**, by at least one restraint **2802***a*, **2802***b*, which is similar to restraints **2400**, **2500**, and limits movement of the layers relative to the shell **2602**. The restraints **2802***a*, **2802***b* may also be the same restraint as the restraints **2400**, **2500** joining internal layers together.
[0246] Each of the restraints **2802***a*, **2802***b* may be a tape, similar to restraints **2400**, **2500**. The tape is configured to limit relative movement between the respective layers and the helmet to about 30 mm, similar to restraints **2400**, **2500** limiting movement between some of the layers to about 30 mm.
[0247] Similarly, in an embodiment in which a headband such as headband **200** or headband **2702** as a whole (i.e. including both external layers) is attached to a helmet, the at least one restraint may also be a tape, and may also limit movement of the headband, or at least some layers of the headband, relative to the helmet to about 30 mm.
[0248] It is noted that the "headbands" **200**, **2702** of the helmets **2600**, **2700** may comprise anterior and posterior portions, and that those portions may have a different number of layers, as set out with regard to the headbands of the disclosure.
[0249] It will be appreciated by those skilled in the art that the "headbands" **200**, **2702** may be attached to the helmets **2600**, **2700**, **2800** so that they cover the desired portions of a user's head, in use. As such, the headbands **200**, **2702** will be worn in the position shown in FIGS. **10** and **15**.
[0250] The helmets of the present disclosure may be configured for use as ballistic helmets, such that transmission of the impact force of a ballistic projectile is reduced, in particular reducing the rotational force imparted by that ballistic projectile to the user's head.

Claims

1-30. (canceled)
31. A headband for protecting a user's head from impact forces, comprising: a first external layer and an opposing second external layer; an impact absorbing layer between the first and second external layers; and a slip layer positioned between the impact absorbing layer and one of the first and second external layers, wherein, upon the headband receiving an impact, the slip layer facilitates relative movement between the impact absorbing layer and the one of the first and second external layers.
32. A headband according to claim 31, further comprising a second slip layer positioned between the impact absorbing layer and the other of the first and second external layers, wherein, upon the headband receiving the impact, the second slip layer facilitates relative movement between the impact absorbing layer and the other of the first and second external layers.
33. A headband according to claim 31, wherein the first and second external layers are joined at, or

near, each circumferential edge.
34. A headband according to claim 33, wherein the first and second external layer form an envelope for enclosing the impact absorbing layer and the or each slip layer.
35. A headband according to claim 34, wherein the impact absorbing layer and the or each slip layer are smaller than the envelope, so that there is a gap between the circumferential edges of the envelope and the circumferential edges of the impact absorbing layer and the or each slip layer.
36. A headband according to claim 31, wherein the material of each layer of the headband is elastic so that, after receiving the impact, the layers of the headband are configured to return, substantially, to their original orientation and shape.
37. A headband according to claim 31, wherein the at least one impact absorbing layer comprises a first impact absorbing sub-layer and a second impact absorbing sub-layer.
38. A headband according to claim 37, further comprising a third slip layer between the first and second impact absorbing sub-layers, wherein, upon the headband receiving the impact, the third slip layer facilitates relative movement between the first and second impact absorbing sub-layers.
39. A headband according to claim 37, wherein the impact absorbing layer comprises at least one further impact absorbing sub-layer.
40. A headband according to claim 39, comprising at least one further slip layer, the or each further slip layer provided between the or each further impact absorbing sub-layer and an adjacent impact absorbing sub-layer, wherein, upon the headband receiving the impact, the or each further slip layer facilitate relative movement between the respective impact absorbing sub-layers.
41. A headband according to claim 38, wherein a material of the first slip layer and, if present, the second slip layer, differs from a material of the third slip layer and, if present, the or each further slip layer.
42. A headband according to claim 31, wherein the headband comprises at least one restraint configured to limit movement of one of the layers relative to another one of the layers.
43. A headband according to claim 31, wherein the headband comprises an anterior portion and a posterior portion, optionally wherein the anterior portion and the posterior portion are joined to each other, and further optionally wherein the headband circumscribes the head through 360 degrees.
44. A headband according to claim 43, wherein the anterior portion comprises a different number of layers than the posterior portion, and optionally wherein the posterior portion comprises fewer layers than the anterior portion.
45. A headband according to claim 44, wherein the posterior portion comprises: the first external layer; the second external layer; the slip layer; the second slip layer; and an impact absorbing layer comprising three impact absorbing sub-layers and one further slip layer; and wherein the anterior portion comprises: the first external layer; the second external layer; the slip layer; the second slip layer; and an impact absorbing layer comprising three impact absorbing sub-layers and two further slip layer.
46. A headband according to claim 43, wherein portions of the anterior portion and the posterior portion are configured to overlap.
47. A headband according to claim 31, wherein a thickness of the headband is less than 15 mm and/or wherein a mass of the headband is less than 100 grams and/or wherein the headband is configured to, in use, cover at least 40% of a user's head.
48. A headband according to claim 31, wherein the or each impact absorbing layer comprises a foam material, and optionally wherein the foam material is a blended vinyl/nitrile polymer.
49. A headband according to claim 31, wherein the first external layer, in use, is adjacent the user's head, and comprises a medical spacer fabric, and optionally wherein the first external layer comprises a gripping surface adjacent the user's head.
50. A helmet comprising a headband for protecting a user's head from impact forces, wherein the helmet forms a first external layer of the headband, and the headband comprises: an opposing

second external layer; an impact absorbing layer between the first and second external layers; and a slip layer positioned between the impact absorbing layer and one of the first and second external layers, wherein, upon the headband receiving an impact, the slip layer facilitates relative movement between the impact absorbing layer and the one of the first and second external layers.