Chapter 8 Impact resistant materials and its potential

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1.0 INTRODUCTION

The incidence of sports injuries in high contact sports such as rugby, football, ice hockey, and baseball is high. These sports have always been played with intense competition such that injuries become inevitable. However, the severity of injuries can be reduced with appropriate training and when protective clothing is worn which has the ability to absorb the shocks or dissipate the energy over a wider area such that it lessens the impact. The protection gear in rugby includes headgear, shirt pads, shin guards and mouth guards. High performance impact protection materials are embedded in the garment particularly in the shoulder, biceps, and chest region. These materials need to be soft, thin, flexible and durable. Commercial products are usually available in various thicknesses and some can be moulded to fit various contours of the body.

In recent years, there has been an increase in the use of such impact resistant materials in sportswear, but some users have expressed concerns about the way protection is incorporated in the products. Some garments have pads inserted into fabric pouches which can move during an impact and are unlikely to remain in its position and protect the wearer during a slip or fall or collision. A few garments possess bulky pads, which inhibit the breathability and restrict the free movement of the athlete. However, most garment manufacturers and sportswear brands claim that padding reduces the risk of injuries sustained in sports. On the other hand, researchers suggest that such padding gives limited protection against fracture and dislocation of joints. In this chapter, a wide range of impact resistant materials used for sportswear are appraised. Injuries sustained in high contact sports such as rugby are identified. Regulations that affect the designing of garments with impact resistant materials are discussed along with illustrations of various commercially available garments with padding. An impact attenuation test which was developed to ascertain the energy absorption characteristics of various commercial materials is described. Various products are compared for their performance and benchmarked against natural materials such as leather. In addition, factors affecting garment manufacturing using these impact resistant materials are presented.

2. INJURIES SUSTAINED DURING SPORTING ACTIVITIES

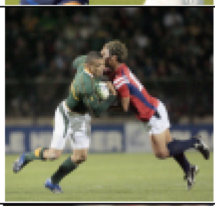
From major competitive team sports like football, baseball, cricket and basketball, to individual sports like cycling, bowling, golf and swimming, the body is at risk to the elements surrounding it when involved in a physical activity. Maron et al (1995) examined 25 cardiac deaths in young adults from sport injuries and found that the cause was impact from a projectile (e.g. a baseball hockey puck). They added that among the sports players, 18 did not wear any protection on the chest zone and the remaining wore some form of protection such as padding. Of the seven players who wore protective gear, four were playing hockey, and other three were in football. In 2010, the National Electronic Injury Surveillance System (NEISS) reported over half a million injuries relating to basketball. Another two million injuries were associated with bicycling, football, and other sports. The highest numbers of sports-related injuries came from bicycling, basketball, baseball, and running. While each sport is played differently, they all take the same toll on the body. Each part of the body is affected by physical contact, collisions and excessive exertion. Some of the most common injuries to the body from various sports are listed in Table 1, obtained from National Electronic Injury Surveillance System (NEISS) that collects injury data associated with consumer products from U.S. hospital emergency department across the country.

Table 1 Sport and types of injury

Sport	Type of Injury	Estimated Number of Injuries
Basketball	Cut hands, sprained ankles, broken legs, eye and forehead injuries.	529,837
Bicycling	Feet caught in spokes, head injuries from falls, slipping while carrying bicycles, collisions with cars.	490,434
Football	Fractured wrists, chipped teeth, neck strains, head lacerations, dislocated hips and jammed fingers.	460,210
ATVs, Mopeds, Minibikes	Riders of ATVs were frequently injured when they were thrown from vehicles. There were also fractured wrists, dislocated hands, shoulder sprains, head cuts and lumbar strains.	275,123
Baseball, Softball	Head injuries from bats and balls. Ankle injuries from running bases or sliding into them.	274,867
Exercise, Exercise Equipment	Twisted ankles and cut chins from tripping on treadmills. Head injuries from falling backward from exercise balls, ankle sprains from jumping rope.	269,249
Soccer	Twisted ankles or knees after falls, fractured arms	186,544

	during games.	
Swimming -	Head injuries from hitting the bottom of pools, and leg injuries from accidentally falling into pools.	164,607
Skiing, Snowboarding	Head injuries from falling, cut legs and faces, sprained knees or shoulders.	96,119

Source: NEISS, 2010*Impact injuries* sustained by sports men and women are increasing due to the competitive nature of sports such as rugby, football, baseball, etc. and they adversely affect their career. The National Sports Medicine Institute, (Nsmi.org.uk, 2009) stated that sports players experience injuries caused by impact or contact with objects, surfaces or other people. Injuries caused by impact and contact occur in common sports such as football and rugby and in more dangerous sports such as motor racing, boxing and skiing. Often, contact with other people can cause an athlete to become off balance, or change direction quickly; this causes damage to the connective tissue and powerful direct contact may also cause a joint to become displaced. Impact injuries often involve spinal injuries, ligament and tendon damage, fractures and head injuries. Rugby for instance, has the highest risk per player per hour of all the major sports, of which 30% of injuries occur in shoulder region closely followed by injuries in the knee area (Funk, 2012). Marshall et al. (2002) reported that rugby is a high contact sport and players are likely to sustain a range of injuries. Table 2 illustrates various injuries that are found to occur in rugby during tackling.

Table 2 Description of tackle types in rugby		
Arm	Tackler impedes/stops ball carrier using the upper limbs	
Collision	Tackler deliberately impedes/stops the ball carrier without using the arms	
Shoulder	Tackler impedes/stops the ball carrier with his/her shoulder as the first point of contact followed by use of the arm(s)	

Source: Fuller, et al. (2010), BMJ Publishing Ltd.

During training, players are known to sustain injuries. Researchers Gabbett and Godbolt, (2010) investigated the incidence of training injuries among professional rugby players and found that injuries were particularly high in the thigh region. Hematoma (a type of injury in legs where blood clots, blood flow is restricted and blood vessels in the injured portion breaks) and muscular strain were associated to rugby players. International Rugby Board regulations allow (IRB) players to wear shoulder pads, provided the pads are made of soft and thin material which may be incorporated in an under garment or jersey provided the pads cover the collarbone and shoulder. The padding material may not exceed 45 kg/m^3 providing maximum coverage to the shoulder region (IRB, 2012). In addition, players may wear shin guards, ankle support, and head gear that conforms to IRB regulation 12.0 (IRB, 2012). Shoulder injuries result in sprains, strains, fractures, and dislocations (Brooks, et al. 2005). Funk (2012) stated that 35% of all injuries in the shoulder region are recurrent ones and the player has a likelihood of sustaining an injury on the other shoulder.

A recent report stated that one in four rugby players will be injured during a season. Rugby injuries are three times higher than football. Most injuries are experienced by youths of 10-18 years and adults aged 25-34 years. In rugby, 57% of most sport injuries occur during matches (rather than in training) and particularly when a player tackles or is being tackled (South Wales Osteopathic Society, 2009). Concussion is an injury to the brain or spinal cord due to jarring from a blow, fall or impact of a collision. In the Australian Football League, concussion is estimated to occur at a rate of approximately seven incidents per team per season (Khurana and Kaye, 2011). Rugby Football Union (RFU, 2002) stated that despite the increased use of shoulder pads from 20 to 36% between 1999 and 2002 there was an increase in injuries from 12 to 13%. Gerrard (1998) noted that shoulder pads do not protect against fracture, dislocation or rotator cuff tears. It has been suggested that shoulder pads may protect from lacerations, reduce bruising and haemotoma of the soft tissue surrounding the shoulder but do not prevent major injuries that result from direct blows to the top of the shoulder or falling onto an out-stretched hand. Recently, Harris and Spears (2010) conducted an investigation on four commercially produced shoulder pads – PVA foam (Kooga, Canterbury, Gilbert and Terminator). They examined material properties by dropping hard and soft objects onto materials protecting a force plate, recording peak impact forces at pre-determined heights and measuring their force-deformation behaviour. Best performing pads were thicker; all pads were able to attenuate force for lower loads however at higher impact loads offered little protection. Pain, et al. (2008) reported *in vivo* effectiveness of Kooga shoulder pads using Tekscan sensors that measured impact intensity on actual tackle on six male rugby players. The researchers reported that pads enabled peak forces to be reduced by 35% (impact with an object) and 40% for all tackles.

Figure 1a: Proportion of injury sustained – adults

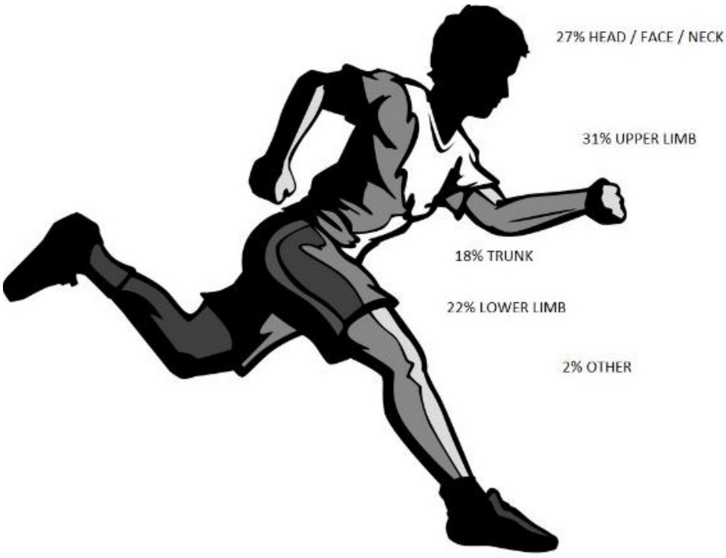


Figure 1b Proportion of injury sustained - children

(Source: Dreamstime - images; www.injuryresearch.bc.ca)

Figure 1a illustrates that adults endure more injuries to head, shoulder and lower limb (thigh) whereas children (Figure 1b) suffer from head/neck injuries followed by the upper and lower limbs.

Figure 2: Rugby player tackling
(Source: Shutterstock)

Approximately half of all injuries occur while a player is tackling (Figure 2) or being tackled. Hookers and flankers sustain the most injuries. Forwards are more frequently injured than backs because of their greater involvement in physical collisions and tackles (The British Columbia Injury Research and Prevention Unit, 2012). A rugby league team consists of 13 players (six forwards and seven backs); each team has sets of six tackles to advance the ball down field. Due to the nature of injuries sustained, players have enforced absences from sports participation. Hence, teams are under pressure to prevent or reduce injuries by requiring its players to wear a protective gear. Figure 3 illustrates a shoulder tackle in rugby known to be associated with higher risks of injury. Rugby is a highly intensive team sport and players move fast in the field. This sport is popular among men; however women are getting more involved in college/school level. As discussed earlier, 40% of injuries are muscular strains or contusions, 30% are sprains, followed by dislocations, fractures, lacerations and overuse injuries. Players' may also choose wear protective clothing (in the form of head gear, padded vests, shorts, shin guards, mouth guards and support sleeves) reduce the risk of sprains and cramps. By 2012 the

International Rugby Board had approved 59 brands that supply a wide range of shoulder padding vests to various teams (IRB, 2012).

Figure 3: Shoulder impact – a close up view of rugby player being tackled

(Source: Dreamstime)

This chapter reflects on the recent exploration of impact resistance materials for sportswear using an experimental approach to gain understanding of material properties using an impact attenuation test (which captures peak forces over time). The chapter focusses on the principles of sportswear design when using impact resistant materials. Figure 4 illustrates a recent rugby match between England versus Italy, where the English player is being tackled and is uprooted from the ground. The speed at which, the collision occurs results in the player falling on the pitch injuring his head, chest, arms and shoulders.

Figure 4 A picture from Mogliano Veneto (Italy): Six Nations 2010, Italy A vs England Red Saxons, Italy's player is tackling hard

(Source: Dreamstime, 2010)

The force of impact during tackling by rugby players is considered to be 1 to 1.3 times of the body weight (Trewarth and Stokes, 2003) with most of the force acting on the shoulder/collar bone zone. Figure 5 illustrates the typical rugby injuries where the direction the force acting on the tackler (shoulder region) during tackling. Moreover, while try scoring the injuries are sustained in the rotator cuff region, when the player slides on the ground.

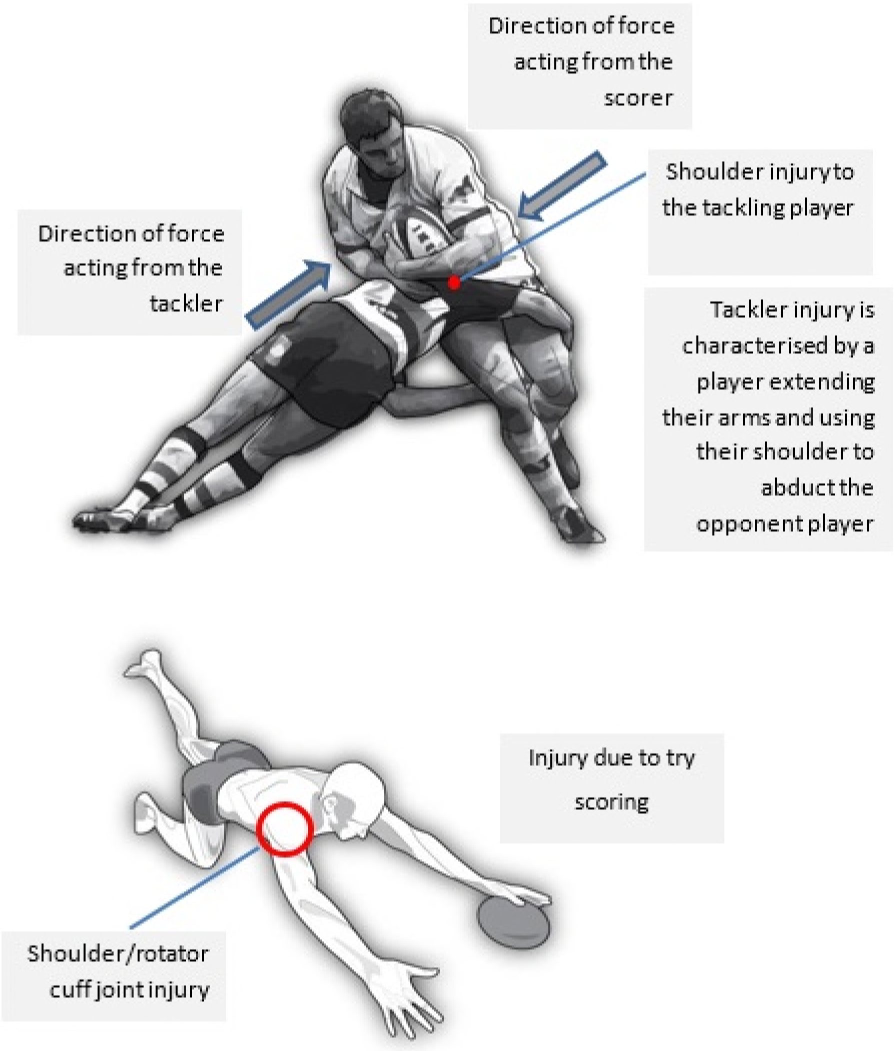


Figure 5 Rugby player tackling injuries

(Image courtesy of Dahan, 2013)

A range of protective materials have been evaluated Coir/EVA as nonwoven impact protectors (Maklewska et al., 2005); polypropylene and flax fibre laminate (de Velde et al., 1998); cellular textile materials (Tao and Yu, 2002) as sports protectors for helmets; 3D spacer fabrics from Dow Corning with various thicknesses and levels of protection (Dow Corning, 2011); Maklewska et al. (2002) compared the impact strength of nonwoven fabric pads intended for protective clothing and sportswear; Roger Co. reported two customisable products composed of Poron XRD material. The two products were extreme impact pad and B-guard. The extreme pad was recommended for knee and elbow pads to shin and thigh protection. It was also reported that the product had a fabric backing that allowed moisture wicking air channels to enhance comfort (WSA, 2011).

Dura et al. (2002) investigated the behaviour of dynamic rigidity on shock absorbing materials (used for shoes) using a visco-elastic linear model. Lam et al. (2004) studied various thermoplastic cellular textile composites with knitted and nonwoven fabrics which were sandwiched between layers of thermoplastic matrix. Researchers reported the effect of impact energy of interlock knitted fabric in a matrix - ultra high molecular weight polyethylene/low density polyethylene on three levels of impact 24 J, 44 J and 119 J. The fabrics were in the form of domed-grids (cellular composites) with domes rising up to 15mm thickness. The fabrics did not collapse with 24 J impacts, but at higher energies the fabric deformed and cells closed. Also, these cellular composites had little recovery soon after impact.

3. COMMERCIALLY AVAILABLE IMPACT RESISTANT MATERIALS

In this section various materials used for impact protection are described. Dilatants are polymer based materials commonly used for energy absorption, which is a shear thickening material where its viscosity is affected by shear applied strain. At low rate of deformation the material remains soft and pliable but at elevated rate of deformation it undergoes substantial increase it its viscosity. Hence, at higher deformation the material becomes stiff or rigid (Palmer and Green, 2010). Generally, the viscosity of material decreases as the shear strain increases but dilatant material are shear thickening material where its viscosity increases as shear strain increases, hence the name, *Non-Newtonian fluid*.

Poron XRD is an open cell urethane foam. When at rest above the glass transition temperature of the urethane molecules, it has softness and flexibility. When impacted quickly, the glass transition temperature of the material drops so that the urethane molecules stiffen to protect the wearer from damage.

D3O is comprised of a polymer composite which contains a chemically engineered dilatant, an energy absorber. This basic material has been adapted and enhanced to meet specific performance standards and applications. The material is soft and flexible in its normal state, however when impacted by force it locks itself and disperses energy and returns to its normal state (D3O.com, 2013).

Ethylene vinyl acetate (EVA) foams are described as a specific type of cross-linked closed cell polyethylene foam. They are designed to be soft, with a rubber-like texture and with good shape recovery after deformation.

Deflexion was created by Dow Corning made of silicon that has been polymerized into a flexible silicone sheets. The company claimed that during a hard impact it acts like a bullet, where all the molecules gather around that area and instantly turns in to rock solid form. They would disperse and absorb the impact, like a bullet-proof vest. The idea is to create a kind of armour that can shift around like clothing in a breathable fashion (Dow Corning, 2012).

Sorbothane – a synthetic visco-elastic polymer (thermoset polyurethane material) used to absorb shock widely used in shoe insoles. It possesses shock absorption, vibration insulation, and damping characteristics (www.sorbothane.com). Cinats et al. (1987) studied therapeutic implications of sorbothane in orthotic insoles which could absorb the energy from foot strike. The sorbothane had some clinical significance, however properties of materials may change when bonded to other substances in production of insoles for shoes.

GPhlex is a similar material but not yet in widespread commercial use. The EVA foam was derived from a Canterbury rugby shirt, and the leather was a sample of unfinished material obtained from cow skin.

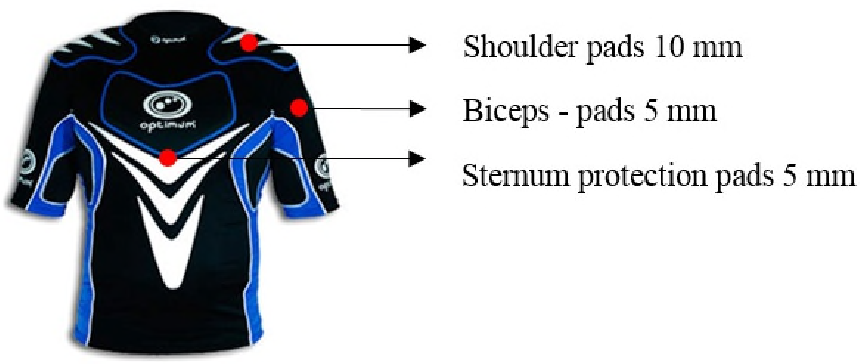


Figure 6 A typical Rugby shirt (Optimum) with impact resistant material insertion

Spacer fabric - A three-dimensional knitted structure that allows cushioning and shock absorbency with excellent recovery properties. Spacer fabrics are complex 3D constructions made of two separate fabric layers connected vertically with pile yarns or fabric layers. The conventional spacer fabrics composed of two surface layers bound with pile yarns are generally manufactured using weaving and knitting technologies (Abounaim et al, 2010).

Figure 6 illustrates a typical rugby top with flexible pads inserted in the shoulder, biceps and sternum region. The pads of varying thickness are included to assist in unrestricted movement. Table 3 highlights various rugby tops and impact resistant materials used.

Table 3 Leading brands providing shoulder pads for Rugby

Brand	Product	Impact resistant materials
Canterbury		IRB approved garment with moulded EVA foam to shoulder, biceps and chest to provide enhanced protection against collision.
Optimum		10 mm EVA foam shoulder pads, 5 mm pads for biceps and sternum.
Kooga- EVX V		EVX protection offers the optimum in fit and freedom of movement. The pads consist of a lycra body, shoulder, sternum, bicep padding, all comprised of high expanded EVA. These pads have been IRB Approved.

4. RATIONALE FOR USING IMPACT RESISTANT MATERIALS

International Rugby Board regulations (IRB, 2012) do not outline the level of protection required of shoulder pads, but stipulates three conditions to be met before the pads can be used in matches. The padding material cannot exceed 45 $kg.m^{-3}$ in density and must provide maximum coverage to the stenoclavicular, acromioclavicular (AC) and glenohumeral joints. Pads must also be subjected to an IRB-prescribed hammer and anvil test, which involves dropping a rigid, flat striking surface (5 ± 0.02 kg) onto a pad resting on a steel anvil.

METHODOLOGY

In order to ascertain material properties of impact resistant materials a range of methods were consulted and, of the many, two methods were suitable. Industrial bump caps (BS EN 812:1997/A1:2001) and specification for head protectors for cricketers (BS 7928:1998) involved a striker falling on a surface, with the protective product experiencing the impacts. The current research reported here focuses on material properties, and because measurements of deceleration are more appropriate to head protection. Consequently, our experimental equipment detects the forces experienced by a transducer attached to an anvil located under the protective material. This method is in line with the IRB prescribed hammer and anvil test, which involves a flat striking surface (5 ± 0.02 kg) falling on to a "pad" resting on a steel anvil (Pain et al. 2008). In this study a range of impact resistant materials were evaluated and this is presented in Table 4.

Table 4 Commercial impact resistant materials with potential for use in Rugby tops

Commercial material	**Notes**
d3o	Dilatant material
poronXrd	Open cell urethane foam
EVA foam	Ethyl vinyl acetate foam
Deflexion S-range Deflexion TP -range	3-dimensional spacer fabric with silicone Dilatant material
Spacer fabrics	3D knitted structure
Sorbothane	Synthetic visco-elastic polymer
Leather	Natural benchmarking material

5. IMPACT ATTENUATION TEST

The impact attenuation test has a striker, a steel ball, falling on to a flat anvil on which the protective material is placed. The pressure sensors are located below the sample material and the forces transmitted through the material by the impactor are recorded in the form of a load-vs-time data set. By varying the diameter of the ball, different impact profiles can be created. The mass/height of fall parameters determines the impact energy. For research purposes, impacts of 5J, 10J and 15J are used. An illustration of the test equipment is in Figure 7.

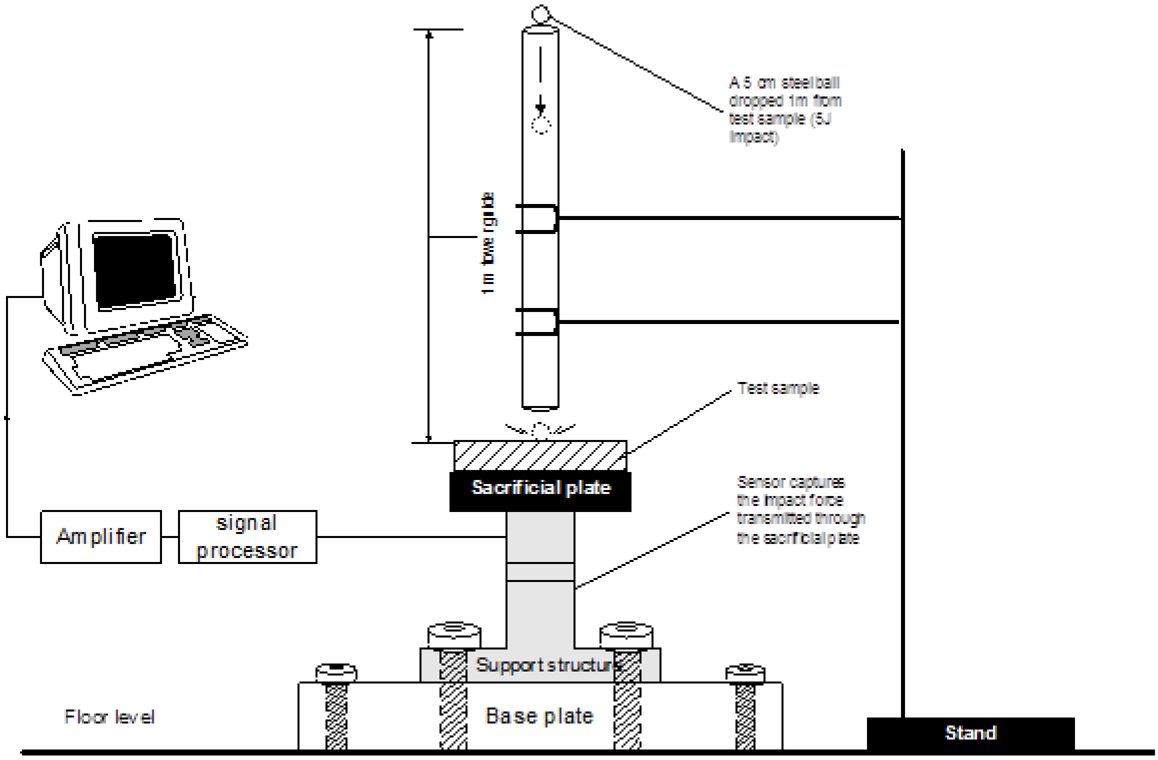


Figure 7 Impact attenuation test rig

Impact forces are experienced by the test material and the forces reaching the support plate are recorded using a load washer. The duration of impact across varying thickness of materials can be measured.

The impact test made use of custom-built equipment from a testing company INSPEC, UK. A typical set of results recorded for a thin (3 mm) material is illustrated in Figure 8. There was insufficient energy taken out by the material, so the ball made a few bounces before coming to rest, and these movements are apparent in the test data.

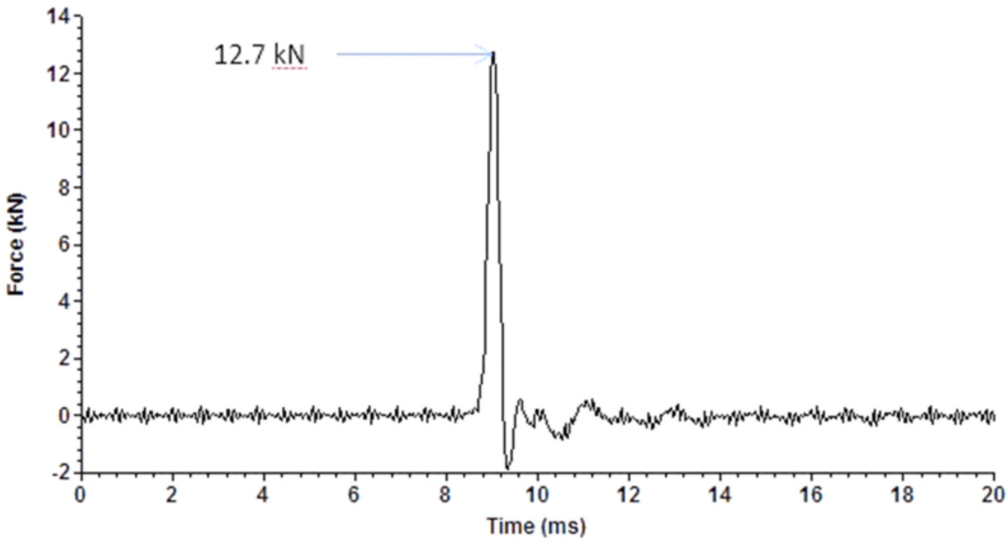


Figure 8 Impact forces experienced with a protection using 3mm Poron XRD

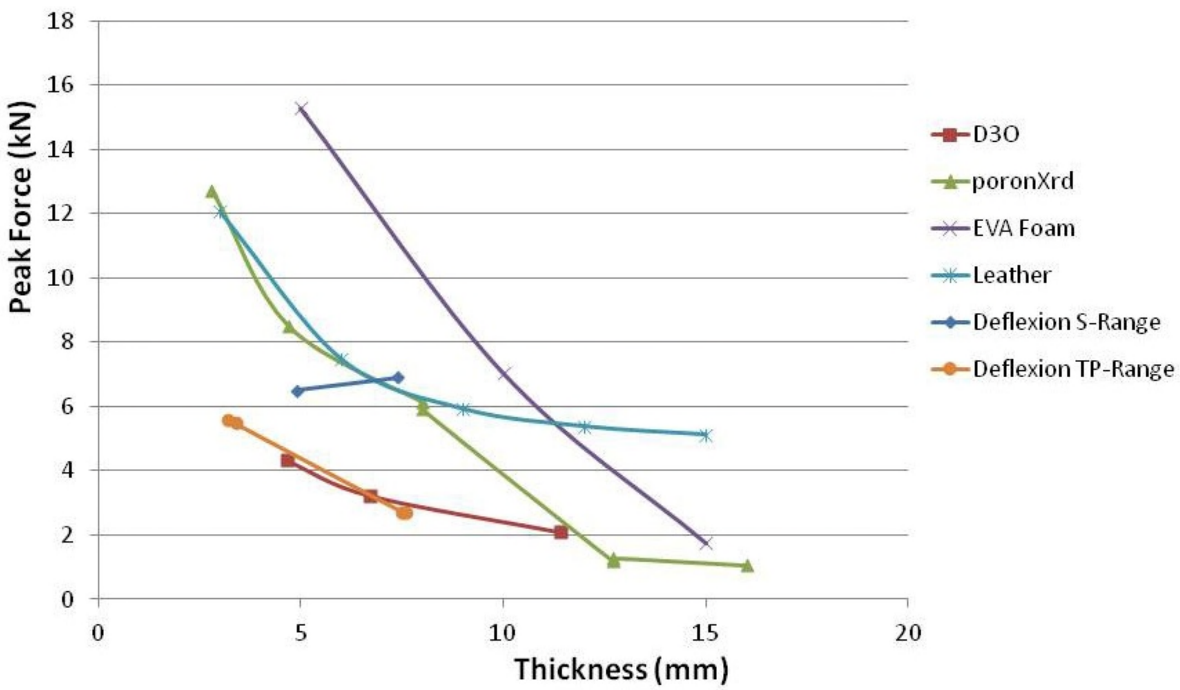
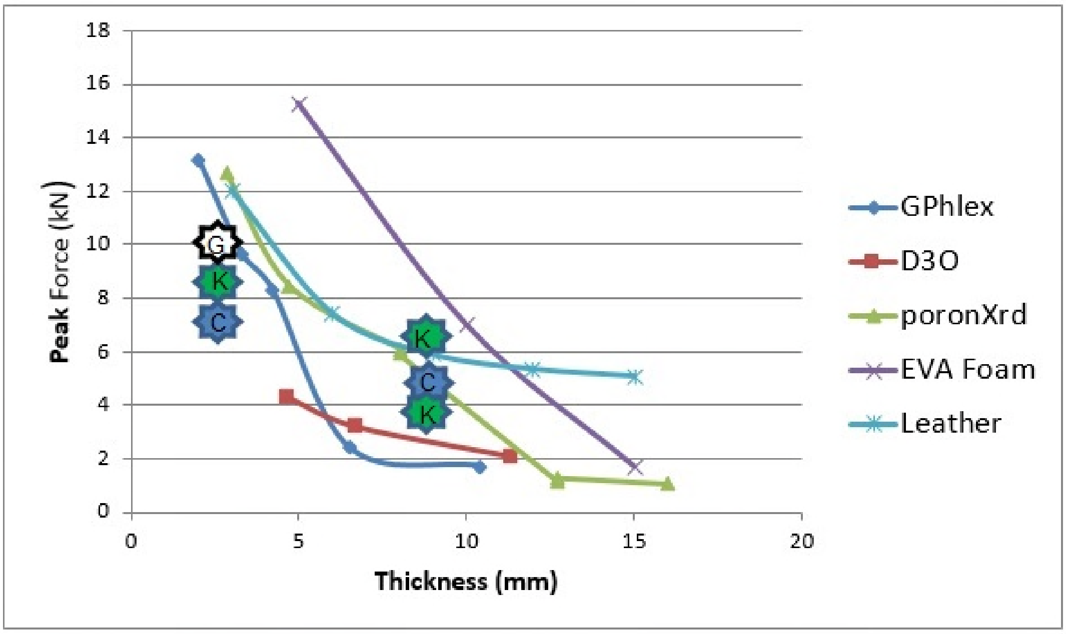


Figure 9 Findings from Impact Attenuation Tests

A selection of materials was tested to compare their abilities to protect against impact. As a control, unfinished leather was tested so that the commercial products could be benchmarked. Leather is a natural material that has been used to provide wearers with some protection. Figure 9 presents peak force variations for a range of materials with different thicknesses. The materials of 2 to 3 mm experienced high peak forces. As thicknesses increase, the commercial products designed to absorb energy and protect against impacts reduce peak forces more effectively than the leather sample.

The EVA foam samples were taken from commercial garments designed for rugby players. Neither the 5 mm (used for arm protection) nor the 10 mm (used for shoulder protection) compared favourably with leather. 10 mm is the maximum thickness permitted by the International Rugby Board for shoulder protection. In general, the branded commercial materials performed better than leather, although less so below 5mm.



G = Gilbert Kryten Xact 10

K = Kooga 20815

C = Canterbury Flexi Top Plus

Figure 10: Peak forces acting on commercially available

The impact protective pads have been randomly selected from commercially products: Gilbert, Canterbury and Kooga. The illustration (Figure 11a to d) shows the tops with protective pads. The pads were also compared with leather, D3O and another proprietary material intended to be used in impact protection (Figure 10). The illustration shows that EVA foam experienced highest peak forces 15 kN at 5mm, whilst Poron XRD and leather performed similar at <5mm, however as the thickness increased Poron XRD sample outperformed leather. As a general trend, most materials less than 5mm experienced high peak forces, but D3O was exceptional than most materials that were benchmarked. The peak forces experienced by D3O at less than 5 mm were low compared to other materials (GPhlex, Poron XRD, EVA form). As the thickness increased the peak forces experienced by D3O was comparable to GPhlex.

Figure 11 a Canterbury Rugby top

Figure 11 b Gilbert Rugby top

Figure 11 c Kooga Rugby top

Figure 11 d Poron XRD sample pads

Figure 11 e G Phlex sample pads

Figure 12 illustrates the broadening of the impact forces resulting from the increasing thickness of a protective material. For clothing applications, this factor is of major importance. It can be noticed from Figure 12 that the peak forces transmitted through the material reduce as the thickness increases from 2 mm to 10.4 mm. This can be attributed to the impact energy being dissipated over a longer time interval within the material. The thicker material provides a cushioning effect such that the impact energy is absorbed and diminished by the material subsequently.

The duration of impact increased from 21 milliseconds to 101 milliseconds, in other words, the material extended the time of the impact with the consequence of reductions in peak values of force. The thickness of material contributes to the reduction of peak forces by extending the duration of impact. This is beneficial in the sense that the material will extend the duration of impact as well as reduce the impact force (absorbing energy) through the material. Earlier research (Venkatraman and Tyler, 2011) revealed that the reduction in peak force with thickness was entirely predictable, as samples of 10mm thickness or more were effective in protecting against 5J impacts and the impacting sphere produced no surface damage. However, at 5 mm thickness the material experienced high impact forces.

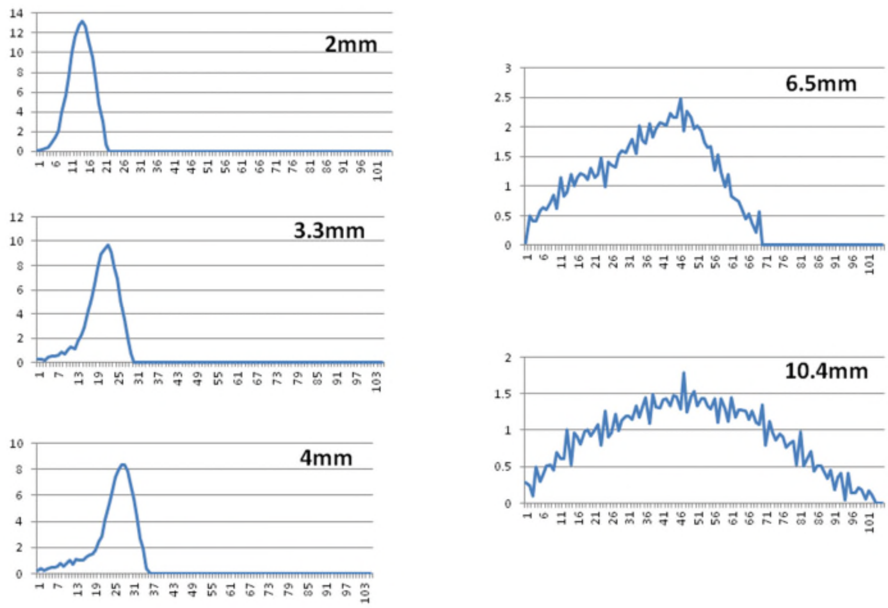


Figure 12 Reduction and broadening of impact forces with increasing thickness

6. REGULATIONS FOR IMPACT PROTECTION

The International Rugby Board which was founded in 1886 and has its headquarters in Dublin, Ireland, is the official governing and law-making body for rugby. In its regulation 12.0 it outlines the provisions of clothing in protecting the athletes and includes, shin guards, fingerless mitts, shoulder pads, head gear, and chest pads as part of their clothing (IRB, 2012).

Figure 13: Shoulder protection in rugby tops recommended by IRB

The impact resistant materials used in clothing should not be affected when exposed to water, dirt, perspiration, toiletries, and during washing. It should also not cause adverse reaction to skin and chaff or abrade the player or any other player in contact. The impact resistant pads should be homogenous which should be of same texture, hardness and density. The sandwiching of layers of pads is not permitted. The edges of the pads should be smooth and no rigid projections which may obstruct players and cause discomfort. Figure 13 illustrates the potential padding zone in a typical top.

Shoulder padding should have a maximum zone of coverage including sternoclavicular (SC), acromioclavicular (AC) and glenohumeral joints (GH). The impact resistant materials will protect the shoulder and collar bone and extend from the neck to a maximum of 2cm down the upper arm. An allowance for padding to cover the SC joint is made to a maximum depth of 60mm and at the back of the neck to a maximum depth of 70mm. The impact resistant materials will have a maximum thickness of 10mm + 2mm tolerance band plus an additional allowance of 1mm on each side for fabric.

7. BENCHMARKING OF IMPACT RESISTANT MATERIALS

The materials widely used in the garments have been evaluated with well-known materials such as leather, foam (EVA and urethane), knitted spacer fabric, and dilatant materials. The impact forces experienced depends on the thickness of materials. Except D3O, most materials in 5mm range were of limited help withstanding high impact forces (Figure 9). It can be inferred (Figure 12) that the thickness of material contributed to reduction of peak forces as well as extending the duration of impact. This is beneficial in the sense that the material will extend the duration of impact as well as reduce the impact force (absorbing energy) through the material. It should also be stated that higher thickness shoulder pads are limited to 10 mm and 5 mm in arms and chest region. The impact attenuation test enabled an assessment of the peak forces experienced from a standardised impact when protected by various materials. This analysis also highlights that there is scope for further development particularly in absorbing shock or impact at lower thicknesses (5 mm to 8mm). As a rule of thumb, the bulky inserts restricts athlete's movement and is uncomfortable to wear.

8. GARMENT DESIGN AND NEW PRODUCT DEVELOPMENT

Rugby tops (long and short sleeve) are made of warp knitted fabric and are designed for a close fit and impact. There are a number of garment design issues which are outlined in Figure 14. Sportswear products require various performance characteristics such as durability, comfort, identity and recognition, and functionality. However, these are dependent on the type of sport, level of physical activity, team or individual sport, intensity of sport, indoor or outdoor sport, frequency, age and other special functions (El Moghazy, 2009). In the context of rugby, with particular focus on protection from impact using pads or materials six factors were selected for discussion. These are: mechanism of injury, flexibility, bulkiness, breathability, thickness and ability to sew these pads on to the clothing. As discussed earlier, bulky inserts are not well received by players as they restrict free movements as well as offer poor comfort. Designing functional protective gear for sports is challenging and demanding since protection is sometimes achieved at the expense of comfort (thick pads, stiff, heavy and multi-layered, non-breathable).

Figure 14: Design issues for rugby tops

DESIGN ISSUES

- Generally, most of the pads or foams, are available in thicknesses above 5 mm and it, become a challenge to incorporate these thick pads in the garment.
- Some pads for shoulders and sleeves lack any moulding of the shape. Pads used in some samples are large and garments do not fit well on the body when pads tend to hold the fabric out.
- Pads used in some products were smaller (shoulder region) which offered less protection to the wearer.
- Seams used in these garments were often over-locked. Some products had body panels sewn together with flat lock seams which enhanced wearer comfort. Other products had pads that were sandwiched between fabrics in form of pouches.
- Thicker foams or pads have perforations to allow flexibility and moisture transport. However at other areas the pads block air/moisture movement allowing low breathability, hence poor comfort.
- Pads were stiffer and allowed very little flexibility to conform to various contour of the shoulder region. Unlike heavy and bulky shoulder pads used for American Baseball the pads used for Rugby vests required flexibility

Figure 15 Typical Rugby vest with padding

(Source: www.kooga-rugby.com)

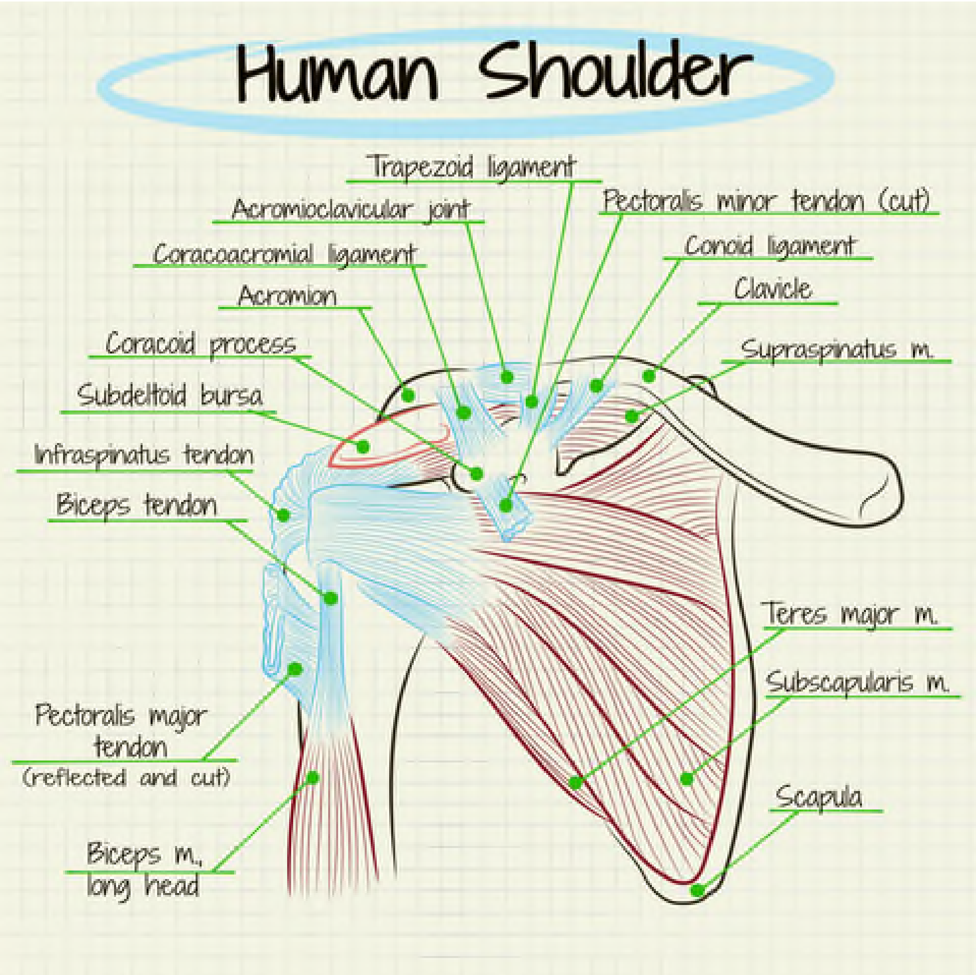


Figure 16 General anatomy of shoulder

Source: © Sfischka | Dreamstime.com

A recent epidemiological study by Crichton et al. (2011) investigated videos of 24 elite rugby players sustaining injury and reported that there were three common injury mechanisms in rugby resulting in serious shoulder injuries – ‘Try Scorer’, ‘Direct Impact’ and ‘Tackler’. It is necessary to understand the nature of the injury and design shoulder padding mechanisms which provide maximum protection to these common injury patterns.

1. Try scorer – out stretched arm when scoring a try,
2. Direct impact - direct blow to the arm or shoulder when held by the side in neutral or slight adduction (moving of a body part toward the central axis of the body).
3. Tackler – it involves a levering force on the glenohumeral joint (GHJ) due to movement of the outstretched arm (Figure 12).

Knowledge of the mechanisms involved in rugby shoulder injury is useful in understanding the pathological injuries and aiding the development of injury prevention methods such as padded vests.

It could be noticed that a typical shoulder padded vest (Figure 15) could provide only a limited coverage to the shoulder region in the context of the findings from Crichton et al. (2011). These design issues should be considered while producing garments for shoulder protection for rugby. The shoulder pads should be flexible to cover the regions as shown in Figure 16 – they are sternoclavicular joint, acromioclavicular, and glenohumeral joint. The padded vest as shown in Figure 10 is less likely to provide protection to these regions satisfactorily. Pain et al. (2008) also reported that when tackled using a shoulder pad the reduction in force was noticed only in the acromioclavicular joint while forces in other areas of the shoulder region was not reduced. In other words, the shoulder experienced considerable impact during tackling. The chapter emphasised the importance of six areas that affect the garment design; they are mechanism of injury, flexibility, bulkiness, breathability, thickness and ability to sew these pads on to the clothing. The industry intends to explore material that is flexible, light weight, breathable, thin and allows easy movement of body. This is based on the principle that the material is able to extend the duration of an impact and the able to broaden the area affected by an impact such that the wearer do not experience peak forces during a fall or tackling.

9.0 SUMMARY AND CONCLUSIONS

Rugby is a fast-paced contact sport that requires precise protection to the shoulder region particularly when players fall without stretched arms (when scoring a try) or tackling an opponent, or experiencing a direct impact onto the ground. Many studies have reported on the performance of protective materials which have been critically reviewed.

Impact resistant materials for sportswear particularly those that are used for rugby have been discussed in this chapter. Ideally, these materials absorb the impact and provide resistance to shocks from a fall or collision. In recent years the use of such protective pads has increased tremendously such that it becomes difficult for the user to make their choices. In addition, it has become a challenge to garment manufacturers to incorporate the pads in the garment. This chapter is concerned with material properties and the experimental work has focused on the forces experienced by a transducer attached to an anvil under the protective material. A random selection of rugby vests was studied and the results are presented. The chapter also highlighted the potential injuries which frequently incurred by athletes during training and playing.

A selection of materials was tested to benchmark their capability to protect against impact. These were compared with unfinished leather: a material offering wearers some protection and used here as a control. Figure 12 presents peak force variations with a range of materials with different thicknesses. The materials of 2-3mm were associated with high peak forces. As thicknesses increase, the commercial products designed to absorb energy and protect against impacts reduced peak forces more effectively than the leather samples. A close examination of the sensor signals revealed that the duration of impact was extended and the forces experienced under the material were correspondingly reduced. Figure 12 documents the change for one particular sample from 21 ms to 101 ms as the thickness increased from 2.0 mm to 10.4 mm. The impact attenuation test records all the forces transmitted through the material and does not illuminate how those forces are distributed at the zone of impact. The areal distribution of forces at the point of impact can be potentially explored using pressure sensors.

Six factors affecting the design and development of performance sportswear are represented in Figure 10. The analysis of a selection of commercially available and IRB approved rugby shirts (with protective pads) using the six factors approach has documented a number of issues for designers and product developers to consider. This analysis provides a framework for enhanced design and for the formulation of design principles for protective sportswear. Mechanisms of injury are discussed to highlight the fact that sportswear development is user centred and it becomes essential to understand the frequency of injuries and various parts of the body being affected during a sporting activity.

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