A Smart textile for measuring the impact of energy used in competitive contact sports

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Technological advances that combine electronics with textile fabrics are becoming more of a reality into modern day wearable apparel. This has fashioned the concept of wearable electronics. More products have become available with some new and innovative applications. There are garments available that are capable of monitoring ECG and blood pressure in order to provide an early warning sign of cardiovascular disease.

Another area of significant interest is the potential to develop garments for contact sports that can measure an impact of force when struck by an opponent. These include activities such as martial arts and boxing. These garments would replace subjective point scoring by a human judge, with an objective system that is far more accurate and precise.

The aim of this research was to develop a concept for electro-conductive and intelligent textiles that could be incorporated into a range of sporting clothing. These could be worn by athletes providing measurable data to determine who is the rightful victor within a contest.

Advances in the technology of electro-conductive textiles combined with modern clothing manufacturing techniques, have made these garments a distinct possibility. This has significant potential to the sporting bodies and to the competitors who participate. Greater accuracy and less chance of human error during a competition could be achieved.

1. Introduction

There are numerous accounts of disputed decisions made by the judges throughout the history of physical contact sports and although the judges may incur disciplinary action from the governing body, the athletes are subjected to psychological knock backs and potentially a large loss of earnings. But despite athletes and coaching staff such as Richie Woodall (Davies, 2011) voicing the need for change, no action has been undertaken to develop a better recording system. Modern advances in electro-conductive textiles, textile weaving, fabric coating, Nano- technology and wearable electronics have enabled new concepts to be realised, and that could have significant impact on contact sports and accuracy of scoring. In order to comprehend how this can benefit the user, there are certain criteria that need to be investigated. These areas include;

- The user requirements in relation to the sport.
- The rules and governing bodies of the sport.
- How electro-conductive textiles (ECT's) provide measurable data.

"As one of the most powerful solicitors of human passion, sporting events have a habit of making just as many people unhappy as happy. This is not always exclusively about winning, for the average fan experiences the full gamut of emotions by the time he leaves a closely contested event..." (Smith and Westerbeck, 2004). This statement can be claimed to be true of all sports, but is more poignant with physical contact sports as a score from an opponent can occur in an instant, making it difficult to measure with the naked eye. There has been an abundant amount of films made to replicate the emotional life of a boxer. The feature movie Million Dollar Baby (Eastwood, 2004) describes the sport as:

'...the magic of fighting battles beyond endurance.... It's the magic of risking everything for a dream that nobody sees but you.'

Therefore, this work focussed particularly on the sport of boxing, particularly amateur boxing due to the fact it is the most watched and played contact sport in the world and its recent growth through greater presence at prominent sporting events such as the Olympics with the introduction of women's boxing in London 2012.

A key aim of this research was to develop a concept where a range of clothing could be designed to illuminate the subjective nature of a judge's decision with a more objective approach using smart textile technology. In order to achieve this aim the following objectives were undertaken:

- To identify textile innovations in relation to electro-conductive textiles within sportswear.
- To establish the requirements from professional boxing a athletes.
- Create and evaluate a conceptual garment from combined elements form objectives one and two.

With the utilisation of modern engineered smart textile materials and the advances of computer and electro-conductive materials greater accuracy and less chance of human error during a competition could be achieved.

2. Review of current scoring methods

Halbert (2003) highlights that boxing dates back to 688 B.C. but documentation of boxing matches that resemble the modern day format date back to early 18th century England. The fights were unrefined as there were no weight divisions, no referees and no predetermined amount of rounds. These fights were long, bloody and often ended with fatal injuries. John Chambers drafted the first list of rules in 1867. The rules became known as the Marquess of Queensbury rules.

- The rules outlined that scoring punches must be delivered to the front of the head and upper front torso using various combinations of punches.

- The ‘rounds’ or number of fighting periods are to be predetermined and should last no more than three minutes with a one minute interval.
- The ‘ring’ or the area the fight will take place should be roped and 24ft² in dimensions.
- A fighter can win by a knockout blow by rendering the opponent unconscious or unable to stand for the ten second count provided by the referee. If a contestant is disqualified for illegal punches or behaviour or if the flight lasts the allocated time the decision is made by the ringside judges. (The number of judges depends on the governing body of the fight. Discussed later).
- The judges score each round ten points to the boxer they thought had landed the most scoring blows in the round and nine points to the looser. If a fighter is knocked to the floor and receives a standing ten count he will lose a point.

Within the sport of boxing there are various governing bodies to manage the sport. They include for amateur boxing: the ABA (Amateur Boxing Association), AIBA (Amateur International Boxing Association) and for professionals: WBA (World Boxing Association), WBC (World Boxing Council), IBF (International Boxing Federation). Each boxing governing body may make individual changes to the rules (Finding Dulcinea, 2012). One example of variations to scoring is within amateur boxing which is scored differently to professional boxing. Terry Edwards, England’s international amateur boxing coach commented on this extensively in a recent BBC interview, “For a boxer to score points, he must hit the head or body of his opponent (figure 1), above the belt, with the knuckles of his gloves. Each ringside judge has a computer-scoring button to press for each boxer, and three of the five must hit their button within one second of each other for the point to register” (Edwards, 2006). Complications arise “When boxers are fighting up close, called infighting, a point is awarded to the boxer with the best of the exchanges” (Edwards, 2006).

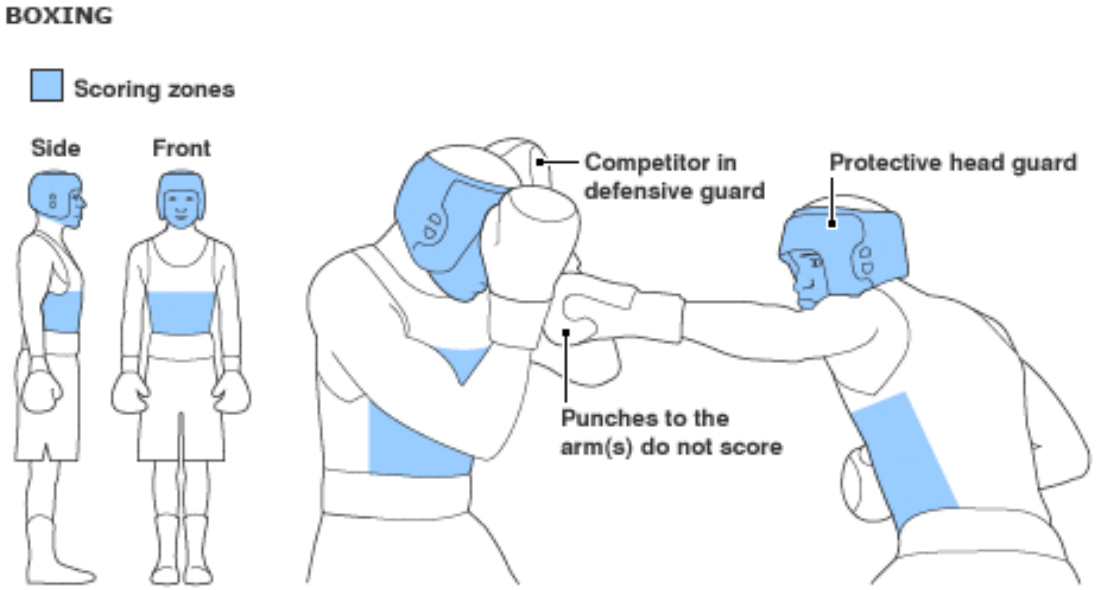


Figure 1 shows the scoring zones of amateur boxing. (Edwards, 2006)

The athletes that participate in the sport are initially divided into two categories, Amateur and Professional. Table 1 differentiates between the two categories and is used by many authors. After a contestant is placed into either amateur or professional they are then sub categorised by their weight to ensure that the fight is as fairly matched as possible. Table 2 illustrates the weight divisions for both amateur and professional boxers as outlined by Hickey (1982). A boxer requires speed, accuracy and power to attain a knockout or a point scoring blow to his/her opponent. During the fight the boxer completes a vast range of movements in the upper torso shoulders and arms to attempt victory. Women have been allowed to compete for the first time in London 2012 Olympics over 4 weight categories (BBC Sport, 2009). This is a good indicator for the growth of the sport as its appeal is becoming far more wide spread and attracting new athletes. Women have also been competing within the professional boxing ring such as Christy Martin; she had signed a contract stating she earns $100,000 per fight. Professional women boxers in general earn substantially less than male boxers. Gotay (2006)

	Amateur	**Professional**
Length of Rounds	2 minutes	3 minutes
Number of Rounds	3-4	4-12
Number of Referees	5 (+1 in the ring)	3(+1 in the ring)
Head-Guard	Compulsory	Prohibited
Vest	Compulsory (either red or blue)	Prohibited (for males)
Weight Groups	11 (defined later)	16 (defined later)

Table 1 highlights the differences between amateur and professional boxing matches outlined by Hickey (1982).

Amateur		**Professional**	
Light Flyweight	Up to 106 lb's (48kg's)	Straw weight	Up to 105 lb's (47.7kg's)
Flyweight	Up to 112 lb's (51kg's)	Junior Flyweight	Up to 108 lb's (49kg's)
Bantamweight	Up to 119 lb's (54 kg's)	Flyweight	Up to 112 lb's (51kg's)
Featherweight	Up to 125 lb's (57kg's)	Bantamweight	Up to 118 lb's (53.5kg's)
Lightweight	Up to 132 lb's (60kg's)	Super Bantamweight	Up to 122 lb's (55.3kg's)
Light Welterweight	Up to 141 lb's (64kg's)	Featherweight	Up to 126 lb's (57.1kg's)
Welterweight	Up to 152 lb's (69kg's)	Super Featherweight	Up to 130 lb's (59kg's)
Middleweight	Up to 165 lb's (75kg's)	Lightweight	Up to 135 lb's (61.2kg's)
Light Heavyweight	Up to 178 lb's (81kg's)	Light Welterweight	Up to 140 lb's (63.5kg's)
Heavyweight	Up to 201lb's (91kg's)	Welterweight	Up to 147 lb's (66.7kg's)
Super Heavyweight	Over 201lb's (91kg's)	Junior Middleweight	Up to 154 lb's (70kg's)
		Middleweight	Up to 160 lb's (72.6kg's)
		Super Middleweight	Up to 168 lb's (76.4kg's)
		Light Heavyweight	Up to 175 lb's (79.4kg's)

Table 2 dictates the various weight classes for amateur and professional boxers. (Hickey, 1982)

Cruiserweight	Up to 200 lb's (90.9kg's)
Heavyweight	Over 200 lb's (90.9kg's)

4. Technological Advances within Electro Conductive Textiles (ECT's)

Tao (2001) highlights that development into intelligent textiles had progressed to a level that makes applications feasible enough to introduce such technologies into a mainstream consumer market. In the previous year to Tao's publication the electronics company Phillips (2000) presented a range of prototype garments that incorporated wearable electronics, some of which are advanced enough to operate within a wireless communication network. All of the examples demonstrated in the publication show an understanding of user requirements, ergonomics and textile adaptation. Dias (2009) clarifies the definition of textile adaptation as he discusses the various methods of converting textile yarns and fabric construction into a working conductive circuit. This technology has been adapted and used within the field of medicine as fabrics are being developed that can act as monitoring devices. In the sporting world there have been numerous innovative applications of electro-conductive textiles and intelligent garments. Such as the Supa-heroe Cycle jacket (figure 2) that has LED lights woven into the organic cotton base. The lights are linked to an on-board speedometer and can change from white to red; this indicates when the bike is braking (Holloway, 2012). Within water sports Quik-silver developed the Cypher electronic heated vest using carbon heating elements sandwiched between layers of neoprene this application is currently being adapted into a snowboarding jacket (Board Riders Guide, 2012).

Figure 2 Shows the Supa-heroe Cycle jacket with incorporated LEDs (Holloway, 2012).

Figure 3 Shows the Quiksilver Cypher heated vest (Board Riders Guide, 2012).

Boxing is a sport that shows signs of growth, in the 2012 Olympics women have been allowed to compete. This sport like others is not free from corruption and if the

fight is not won via knock out the decision is based upon the subjective opinion of the judges. It is unknown how many fights are decided by a judge's decision but there are many accounts of poor decisions. The largest supplier of boxing clothing has not attempted to adapt the clothing to better the sport by eliminating poor decisions. Clothing remains focused on protection, identification and comfort. There have been significant advances within the textile industry especially within electro conductive textiles and Nano coatings that enable textiles to become a part of an integrated electrical circuit. These advances have begun to be used within the medical and automotive industries. To date electro-conductive textiles have not been applied to boxing in any form, but by harnessing simple electrical engineering and textile knowledge, a range of wearable electronics could be developed that could potentially benefit the sport in the same means that the body-wire technology modified fencing.

5. Applied research methods

In order to achieve the aim and objectives, several research methods where used to acquire the data. The study utilises a qualitative methodology underpinned by secondary literature. The results from the market analysis, secondary and primary data collection was triangulate to enable a high-tech product concept to be presented. This paper consolidates the findings of the research and presents the product range.

5.1 Market Research

Qualitative data was used both by questionnaires and semi-structured interviews that was conducted to gain an overview of opinions by professionals in the sport. The end outcome was to retrieve detailed data relating to the boxing industry. 50 questionnaires were given to boxers of gyms located within the Manchester area. Three gyms were used in the sample twenty-two participants completed the questionnaire, which represents a response rate of 44%. It is acknowledged that prior to product launch the sample would need to be extended to reduce bias.

5.2 Technology Methods

An analysis of smart technologies currently used in the development of textile products was undertaken and a method of measuring and converting this data was recommended.

5.3 Design Methods

A conceptual range of sporting clothing for physical contact sports, specifically designed to measure the impact of energy was recommended for future product development.

The Use of ‘mixed methods’ allows a strong variety of quantitative and qualitative information (closed question based questionnaires and semi structured interviews), these techniques permit good triangulation during analysis.

6. Results and Analysis

Five interviews were conducted in total, three were from coaching staff and two were competition level athletes. All criteria and credentials of the interviewees are listed below

Interviewee 1

- *Name: James Barker ‘Jimmy’*
- *Time Boxing: eleven years*
- *Time Coaching: Thirty-two years*
- *Coaches: Amateur and Professional*
- *Coaching Gym: Middleton Boxing Gym, Middleton*
- *Career Highlight: ABA international England coach for Commonwealth Games.*

Interviewee 2

- *Name: Charles Grice ‘Charlie’.*
- *Time Coaching: forty-nine years.*
- *Coaches: Amateur but did coach professional.*
- *Coaching Gym: Droylsden ABA, Droylsden.*
- *Career Highlight: Coaching in South Africa.*

Interviewee 3

- *Name: Antony Newell ‘Tony’*
- *Time Coaching: Six years.*
- *Coaches: Amateur and Amateur international.*
- *Coaching Gym: Shannon’s ABA, Openshaw.*
- *Career Highlight: Training athlete 1.*

Interviewee 4

- *Name: Athlete 1.*
- *Boxing for: 8 Years.*
- *Coached by: Antony Newell.*
- *Attended Gym: Shannon’s ABA, Openshaw.*
- *Career Highlight: Competing at Common wealth Games.*

Interviewee 5

- *Name: Sam Makin*
- *Boxing for: Five Years*
- *Coached by: Charles Grice*
- *Attended Gym: Droylsden ABA, Droylsden.*
- *Career Highlight: Two amateur competition level fights*

Results from the interviews indicated that all of the respondents were in favour of some form of automated point scoring within the sport. All of the competitors had at some point experienced what they considered to be a bad decision by a judge.

From the respondents who completed the questionnaire all of the people were amateur boxers. Figure 2 shows the number of fights each boxer has had in their amateur career.

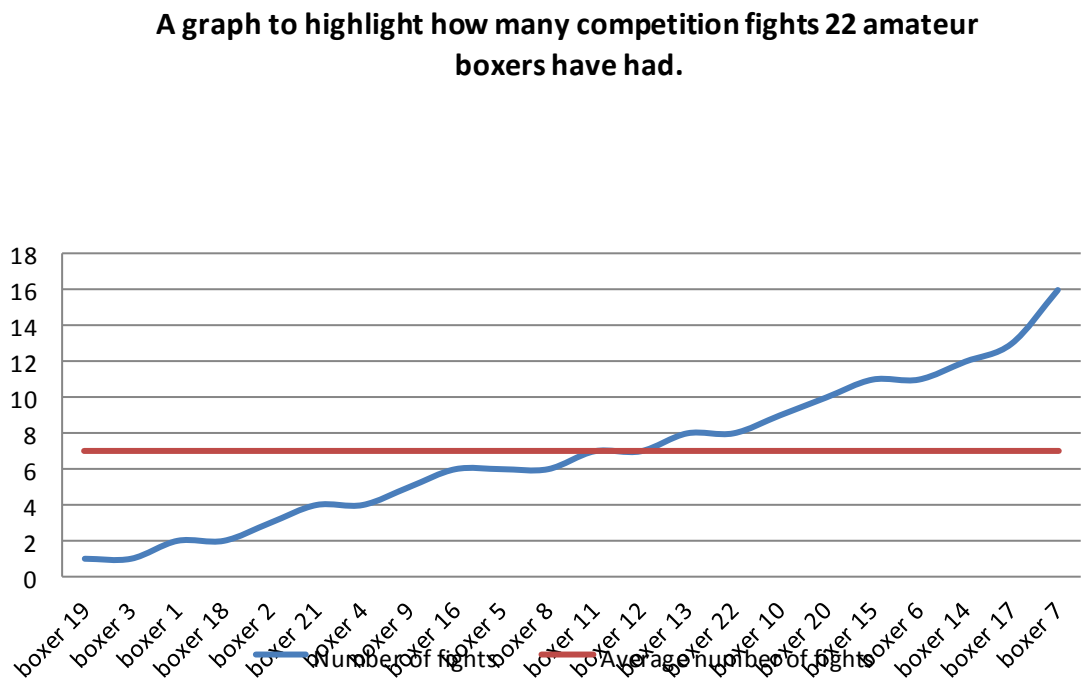


Figure 2: The number of boxing fights per boxer

Of the twenty-two boxers a total number of one-hundred and fifty-one fights had taken place. The graph shown in Table 4 has been filtered to arrange the results in ascending numerical order the average number of fights per athlete worked out to be 6.8 rounded up to 7. From the one-hundred and fifty-one fights it was interesting to see that only 6% of the flights were concluded by a knockout blow. Figure 3 shows how many fights are decided by the judge's decision. From the combination of the interviews conducted and the completed questionnaires there are mixed opinions

about the use of judges in a boxing fight. James Barker and Antony Newell believe there are lots of inconsistencies with the judging. “Well it is ambiguous. In the championships in amateurs you do have the 5 judges using computer scoring. The 5 judges are around the ring and three of them have to press the button with one second of each other to score the point. Now a lot of the judges are old and their reactions aren’t as quick let’s say. Or they can be a little bit more lenient to one fighter than the other and purposely being a little bit slower so their point might not be scored” (Barker, 2012).

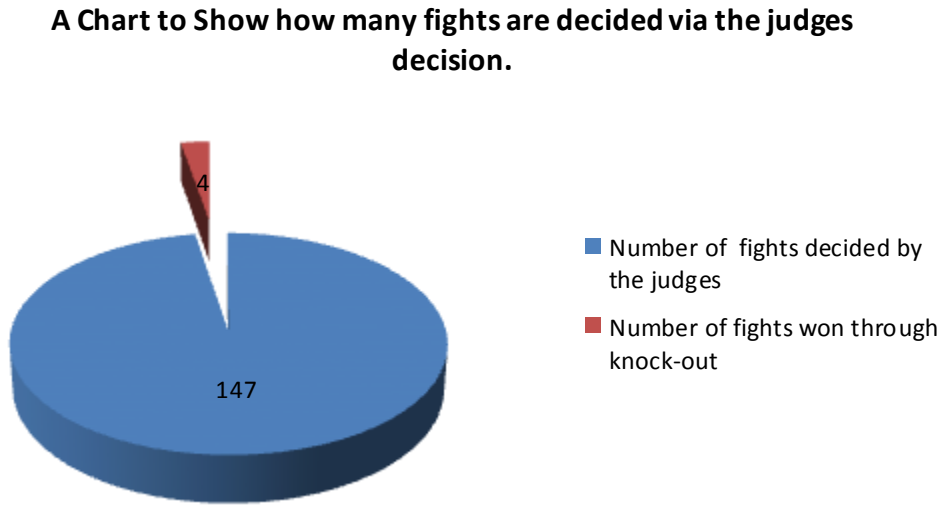


Figure 3: Number of fights per judge’s decision

Despite the majority of athletes agreeing that the judges were the best method to decide the victor of a fight once it has gone the distance, once presented with the concept of the new electro-conductive range of garments 85.5% thought that if the range could be developed it would be a good idea to revolutionise the scoring system of the sport. Of the people that think the garment is a good concept, a further 73.6% would wear the garment if it is uncomfortable (Figure 4).

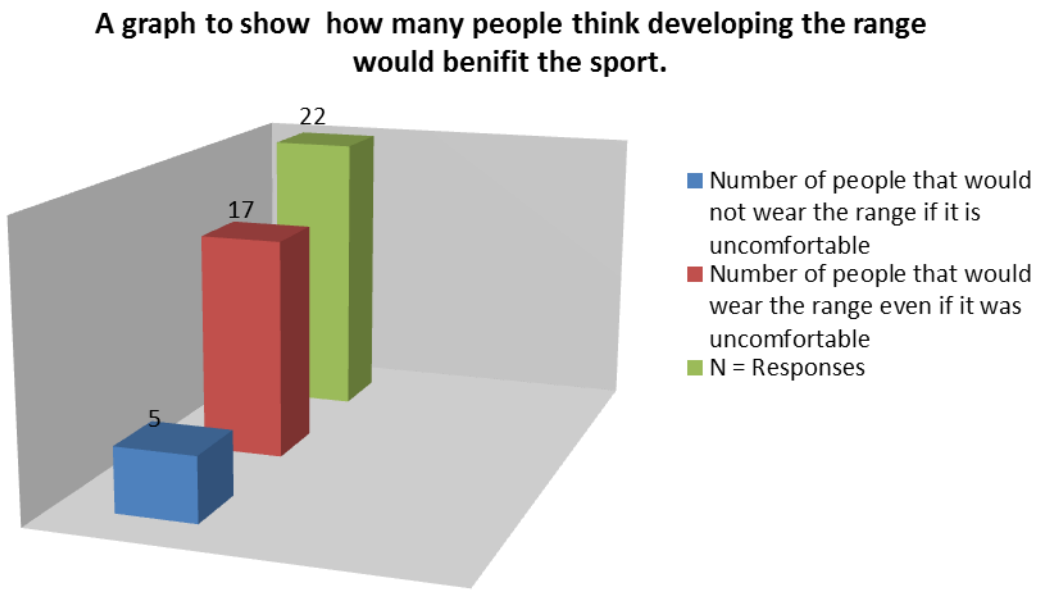


Figure 4: Number of athletes that think the range will benefit the sport

6.1. Acceptance of the Range from the Sports Governing Bodies

After generally concurring that if the range could be developed it would benefit the sport, the athletes were asked if they believed the governing bodies (mentioned in the literature review) would accept and incorporate the range into the clothing required to participate. It was a relatively equally split decision from the athletes perspective, 59% said yes they thought the range would be accepted and 41% saying no (Figure 5).

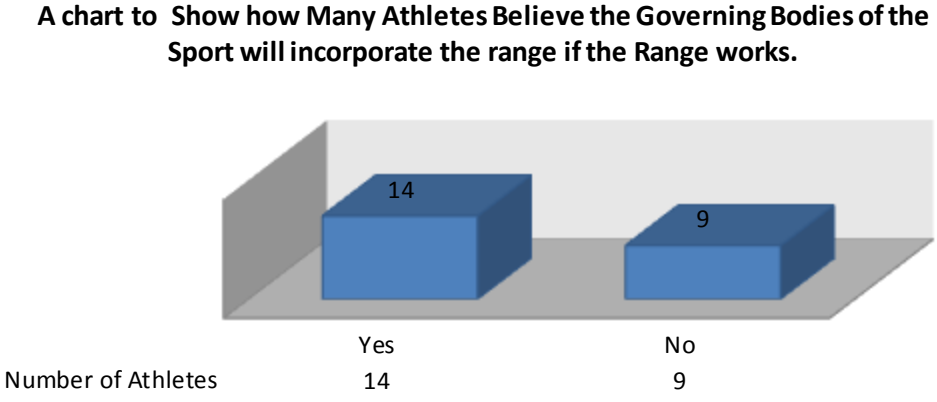


Figure 5: Showing how many athletes believe governing bodies of the sport will incorporate the range

Regulations of amateur boxing state that competing athletes must wear headgear and vests. Also mentioned was that due to the headwear, knockouts are less common within the amateur sector of the sport but, athletes have adapted there style of fighting selecting combinations of accurate punches that will score points. This information and the inability to discover why professional boxers are prohibited from wearing vests have led to a change in direction for the product development process. Therefore the range was focused towards amateur boxing and the range has been developed accordingly.

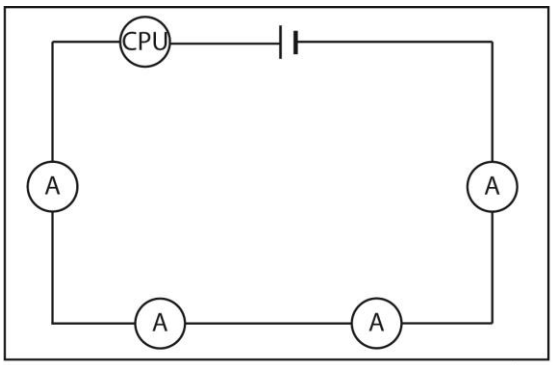
The three garments to be developed are:

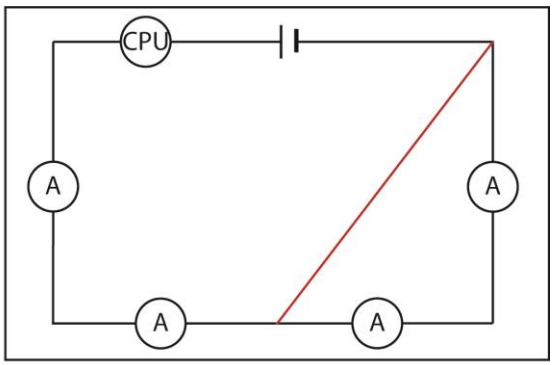
1. A vest
2. Protective head gear
3. A boxing glove

6.1.1. How the Electro-conductive Textile Forms a Circuit That Can Provide Measurable Data

Imbedded ammeters in the vest and headgear register the change in current and the send the data to the Central Processing Unit (CPU) which broadcasts the data to a computer. This works in a similar method as a heart monitor sends data to a watch.

Below are illustrations to highlight the concept.





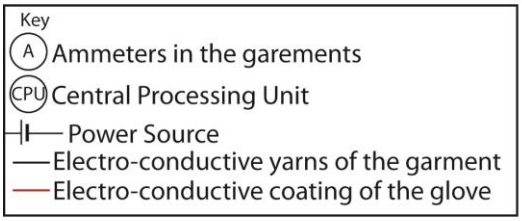
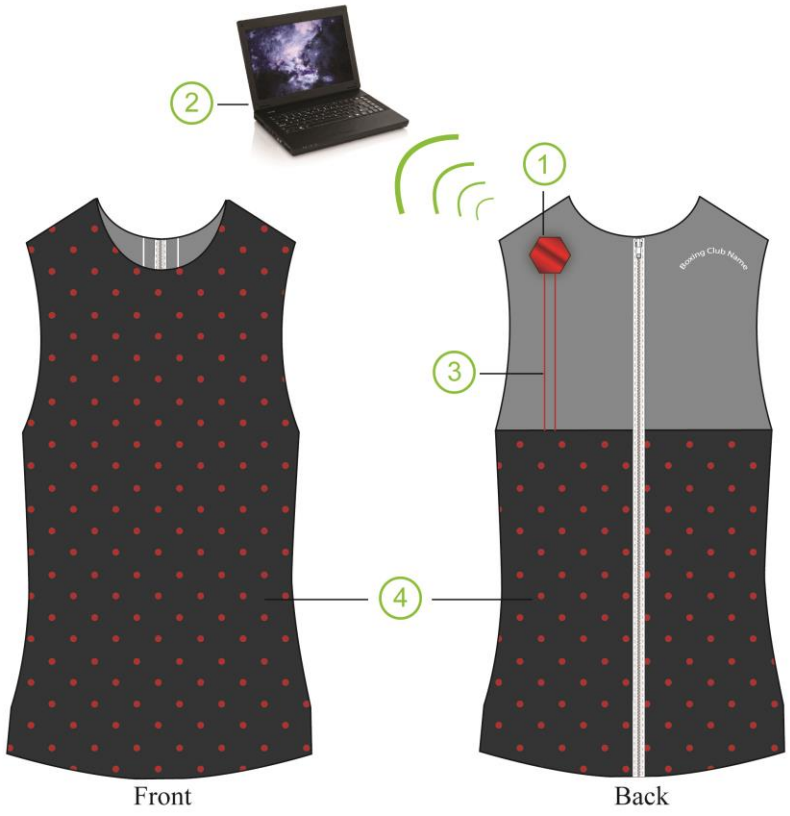


Figure 4 shows the electronic circuit of the vest and head wear and on the right is how the length of the conductor will change when the glove contacts the vest or headgear and how the ammeters will pick up the reading.

6.1.2. Fitting the Vest

As the glove is a generic size and the head gear is adjustable the only garment that requires fitting is the vest. The closer fitting the garment the less likely the fabric is to shift during movement. There has been certain design features included to reduce fabric shifting that will be discussed later. To achieve a fitted vest the athlete will have to be body scanned as certain body scanners can measure dozens of increments to within the upper torso this will provide for a closer fitting garment. The technical spec of the garment is given in figure five. All of the products included within the conceptual range have been designed as close to AIBA approved products currently on the market (Boxfit UK,2012, Online). This is to improve the possibility of authorization from AIBIA and in turn improve the chance of the range being incorporated into the sport. All of the differences are included to improve the performance of the garments.



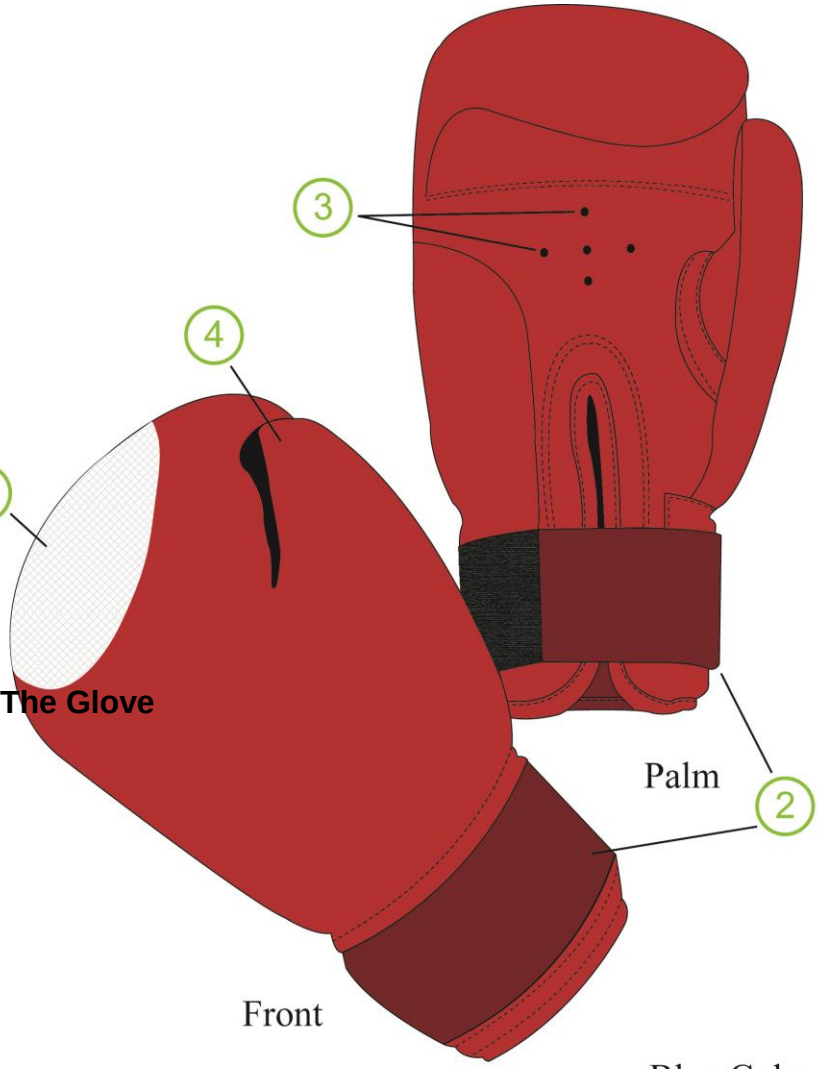
Features

1. The CPU and the power source are mounted at the back shoulder and can be removed which makes the garment completely washable.
2. The CPU transmits the data wireless via bluetooth to a laptop where the judges can see.
3. The electro-conductive channels are knitted into the non conductive area as explained later.
4. The ammeters are located all over this area highlighted in red. The more ammeters there are the more accurate the readings. They are located in non- scoring locations to highlight illegal punches as well.

Key

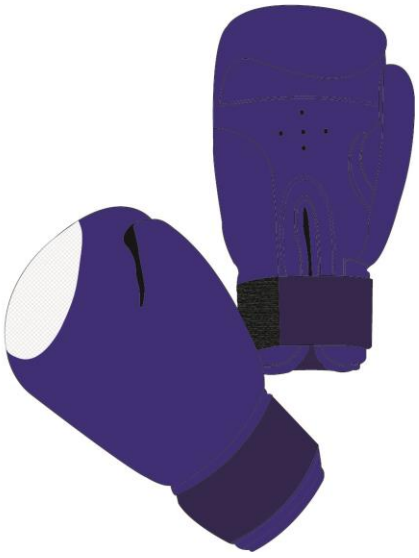
Non-conductive area Conductive area Ammeter location within conductive area

Figure 5



6.1.3. The Glove

Blue Colourway



Features

1. Scoring punch zone: Electro-conductive coating
2. Velcro wrist straps
3. Ventilation holes in palm
4. Separated thumb

Please Note: This is a replica of an AIBA 10oz glove. made of leather. The only difference is the punch zone has an electro-conductive coating.

6.1.4. The Head Gear

Features

1. The CPU and the power source paired with the vest. Note there is no electro-conductive channels, this is because the CPU is located directly on the conductive area.
2. The CPU transmits the data via bluetooth to a laptop the judges can see.
3. The electro-conductive area coveres the whole of the front and side of the head as these are the scoring area.

Key

Non-conductive area. Conductive area. Location of ammeter.

7.0. Conclusion

The electronic elements of the range were designed to be as simplistic as possible to reduce the chance of product failure. In his evaluation Evans (2012) agrees that the concept is ‘most defiantly plausible’ and that far more complex electronics are being applied to clothing such as ‘motion and proximity sensors’.

Although the initial concept of the electronics is plausible Evans highlights that there are still aspects that would require further fine tuning, elements like:

- The type of the power source and ammeter.
- The location of the CPU.
- The weight and density of the fabric.
- The sensitivity and range of the ammeters.

The simplistic nature will also make the products cheaper and more accessible to a wider consumer base. This is a benefit because if the range is tried and tested as a training tool the transgression into competition wear would far less complicated. Barker agrees with this as in his interview he suggests that if the range is not taken into competition wear that it would be useful to develop skill sets for amateur boxers.

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