Abstract

The discrepancy of performance among competitive athletes is getting smaller and smaller. Therefore wearing high tech textile could help to get advantage over competitors. For this reason a lot of investigation has been done on developing high tech textiles that support the athletes to better performance. The aims of this study were to give an overview on the available products and to evaluate their level of innovation. Furthermore the research project should reveal which products are effectively used in trainings and competition. Finally the study elicits the status of current research and shows prospective research potential.

Keywords: performance; competition sports; compression garments; smart textiles; wearable technology

1. Introduction

Success in the international competitive sport is based on equipment besides pivotal factors as training, alimentation and psyche. Therefore a lot of sportsmen and women look for advantage over their combatant wearing appropriate high-tech-textiles. The term “high-tech-textiles” comprehends compression garment, smart textiles and wearable technologies. Smart textiles are made of materials that can adapt to environmental factors. E.g. phase change materials, which have either a cooling or warming effect depending on environmental temperature or shear sensitive materials reacting on mechanical changes. Wearable technologies are textiles that have an integrated sensor, e.g. shirts for monitoring vital parameters during sports. A lot of research was done in this field during the last years and many innovative solutions were brought on the market. Therefore the aims of this study were to give an overview on the available products, to find out, which products are used by the athletes, to figure out the state of current research and to point out further prospective research potential.
2. Methods

The study approach is divided into two parts: data collection and data transfer to a matrix. In this way data were structured and evaluated according to their grade of innovation.

2.1. Data collection

To assess the status of current research and the stage of development of high tech textile three strategies were pursued. First of all data were collected through a literature research in data bases and research engines. All in all 347000 sources were found. Out of this data sources only relevant information concerning competition sports were evaluated. Further to profit from expert’s knowledge seven experts were interviewed from the fields of sport textile industry, the wearable technology and from the field of orthopaedic technique. Finally an online query was launched addressing athletes, coaches and their medical staff. The aim of the query was to find out which high-tech textiles are actually used in competition and training.

2.2. Matrix-data structuring and evaluating

The comprehensive data from the literature research and the awareness from the survey and interviews were displayed in a matrix (table 2). The rows describe the different mode of operation concerning the performance enhancing effect; the splitting is made to evaluate the characteristic of the different enhancing outcome.

3. Results

3.1. Compression Garments

Interviews: The statements of the different compression garments producers were consistent. All of them underlined, that compression garments achieve positive effects on biomechanical and physiological parameters. The advantage results in an increased venous return, in a faster transport of waste products out of the muscle and a better oxygenation of the muscle, in an augmented endurance capacity and muscle force, an impairment of muscle wear caused by muscle vibration, a better control of body temperature and an augmented proprioception. According to manufacturers compression garments are used in almost every discipline, even if they are most popular in endurance sports. The mentioned textiles are more common in USA and Australia than in Europe.

Online query: In total, 34 athletes, 16 coaches and 10 members of their medical staff participated on the query. Among the athletes compressions garments do not seem very popular. 50% of them have never heard about them. 50% of the sports man and women use compression garments during competition, 53 % respectively 57 % neither use them during training nor for regeneration. 50% of the coaches suggest wearing compression garments for better regeneration. The medical staffs advise to use compression garments during training (40%) and regeneration (47 %). None of the groups thinks that compression garments have a positive influence concerning the force. A large number of the coaches (40%) and the medical staff (38%) think that muscular exhaustion can be delayed with the help of compression garments. All of them believe, that compression garment have an injury preventive effect, especially coaches (50%) and athletes (48 %).

Literature research: Several studies have been done to prove the effectiveness of compression garments, in particular the improvement in performance during training and regeneration. To evaluate the effect, the following parameters were analysed: physiological parameters as heart rate, VO₂ max, blood lactat concentration and biomechanical values like muscle vibration and propriozeption. The exploited studies differed a lot in their study set up. Differences were apparent according to the moment the textiles were worn (during the training, for regeneration or for both of them), the number of test persons, the professional condition of the athletes, the intensity of the exercise and the analysed parameters. The compression garments in the research program of Chatard et al. [1], French et al. [2] and Gill et al. [3], served as regeneration tool, whereas in other studies the test persons wore the
compression garments just during the activity [4,5,6,7]. In some studies the athletes were endowed with compression garments during both periods [8,9]. The compression textiles were either tested during team sports specific circuit [6,7] or during endurance training [5,9]. According to the very different study set up the results diverged enormously. Dascombe et al. [5] could note a positive effect on the raised force, the mean sprint time and the jump height when athletes used compression garments. In other studies these effects were confuted [6]. The use of compression garments lead to less muscle soreness by the test persons of Duffield et al. [8] and Trennel et al. [9].

3.2. Smart Textiles

**Interviews:** Functional textiles support primarily the thermoregulatory processes and therefore enhance performance. These textiles work according to the physical law of diffusion and impulse. The effectiveness of the material itself is up to now mainly proved in lab tests. Only a few manufacturers test the whole product on test persons. But according to the interview partners the cut of the clothes plays an important role for the performance.

**Online query:** 66% of the medical staff and 60% of the coaches suggest the athletes to wear functional textiles during trainings. 74% of the sportsmen and women follow this advice. In respect of their impact concerning performance improvement, coaches are very sceptical. Instead 66% of the medical staff, 40% of the coaches and 44% of the athletes think that the functional clothes have a positive effect on thermoregulatory processes. 54% of the medical staff, 57% of the coaches and 47% of the athletes want researchers to put more effort into the investigation of the performance enhancing effect of the functional clothes.

**Literature research:** The physiological effect of functional textiles is to support the athletes in their thermoregulation and protect them against cold and wind. Rieländer [10] brought the importance of the functional clothing to expression. He showed that unsuitable clothes influence the performance negatively. Gremion et al. [11] agreed in this opinion. This study revealed that clothes with better water vapour permeability minimised the stress on human body. This was refuted by Feyerabend’s [12] research. Often applied in sports textiles are phase change materials (PCM). PCM can change their state of aggregation depending on environmental temperature from solid to liquid or solid to gaseous. Thereby the textiles save warmth energy from the warmer body and give it back if required. Purvis et al. [13] carried out a study with goal keepers’ gloves containing PCM materials. In the study the test persons carried out specific exercises with a PCM glove and a common one. The results questions the effect-wise from PCM materials as goal keeper’s hand temperature was warmer with the PCM gloves than with the common gloves. The advantages of smart materials due to biomechanical effects were studied primarily in swimming suits. Apart from choosing the appropriate material the structural composition of the textiles plays an important role. After Toussaint et al. [14] the water resistance during swimming consists of friction, form and area resistant respectively. Therefore the impact of swimming suits design on energy expenditure and swimming kinematic was studied [15]. For the test, different swimming suits were used either with different length or surface structure. One of the wet suits had a mechano-chemical coating. This coating was advantageous in respect of the water resistant effect and the measured linear velocity of the pelvis. Dantas et al. [16] could show a positive effect concerning the water resistance of wet suits, too.

Functional textiles can have a preventive effect either in a physiological way or in a mechanical one. Upton et al. [17] could show a positive effect of thermo trainers on persistent knee tendon inflammation. Schmitt et al. [18] proofed the damping potential of goal keepers’ pads. They could show that the padding does not protect the pelvis well enough and they propagate to invent intelligent protectors.

3.3. Wearable Technology

**Interviews:** As experts presume wearable technology becomes more and more popular in sports and will therefore be established very soon. They think that wearable technologies have a great potential in improving
performance. At the moment problems to be solved are: the mechanical resistance of the sensors, the extent and weight of the batteries and the high prize.

Online query: The results show that up to now movement monitoring is hardly ever used, even if 40% of the coaches and 26% of the athletes wished to have one. 57% of the medical staff, 60% of the coaches and 74% of the athletes would appreciate to have a shirt measuring vital parameters during activity.

Literature research: Wearable Technology stands for textiles in which sensors and wiring are directly integrated into the textile. With this technology it is possible, to measure vital parameters like heart rate, blood pressure, body temperature and respiratory sounds directly without any further devise. Up to now these features are mainly used in the sectors of medicine and work protection. Therefore numerous studies on this topic were found of which some shall be mentioned representatively. There are several studies reporting about different possibilities of integrating wearable technologies into textile for measuring vital parameters [18,20,21]. Besides monitoring vital parameters and biofeedback the analysis of movement is of great interest. There have several investigation been done to detect the movement during impact and release of human body with strain gauges und pressure sensors [22,23,24]. Mazzoldi et al. [25] developed a whole body movement suit. The usage of wearable electronics in the sports field is compared with the health sector really rare. Nevertheless there are some innovative products available on the market, e.g. the “miCoach” training system that can track movements and the intensity during exercising. Or an innovative skiing coach invented by a spinoff company “Moticon” from TU Munich. The skiing coach consists of an intelligent pressure sensitive sole and a conventional mobile phone. Due to the pressure sensors the posture of the skier can be detected during downhill skiing and the information can be sent to the mobile phone over ANT. The mobile phone gives than an auditory feedback, though the driver can revise his posture during skiing. A further promising product is an “Electronic Body Protector” that is used in Taekwondo. In the protection west there is a pneumatic systems integrated, measuring impacts of punches or foot kicks. Measured dates are sent over Bluetooth to a computer.

4. Discussion

The results of the literature research, the online query and the expert’s interviews were transferred to the matrix below (tab. 2) and their different effects were evaluated according to the criteria of tab. 1.

4.1. Compression garments

The compression technology has been applied for medical purpose long time ago. Therefore the grade of innovation is low. Concerning the performance improving effect opinions break up. In the field of research this discrepancy could result from the various designs. In most of the studies the amount of test persons is too low to get statistical significance. Further the level of performance and the test person’s age is not comparable. The intensity of the test, the test material and the sport discipline differed in each investigation program. No double blind study was conducted though it is not to gather that the psyche has great influence on the test results. The different attitude towards compression garments of the athletes might be due to the lack of experience.

4.2. Smart textiles

According to the experts the grade of innovation of smart textiles is very high. They grant a high potential to endorse performance physiologically or biomechanically. But up to know they are seldomly processed in sport textiles. Nevertheless some studies were conducted testing their efficaciousness. The performance enhancing effect of these clothes is argumentative. This could be due to the fact, that most of the studies were done in the eighties, but in the mean time a lot of new products came up.
4.3. Wearable textiles

The results from the literature research, the interviews and the online query show, that the grade of innovation of wearable electronics are rated very high. But there is hardly any study that proofed the wearable’s on a performance improving factor. The accumulation of literature shows an enormous potential of wearable technology in the sectors of health and work protection. According to the experts, the sport opens a huge field for these new products. It should be now the aim to transfer the know how in the field of sports.

Table 1. Criteria of evaluation

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<td>2. Improvement in performance</td>
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<td>3. Application in competition sports</td>
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<td>4. Extent of scientific evaluation</td>
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Table 2. Matrix 1

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5. Conclusion

There are further studies necessary to proof the effectiveness of compression garments. To gain statistical significance a bigger amount of test persons would be necessary. In addition one should figure out at which point, before, during or after the training the compression garments should be worn. Apart from laboratory test field tests with an appropriate amount of tests persons should be realized to evaluate the performance enhancing factors of smart textiles. Furthermore should be analyzed how the comfort of smart textiles influences the performance. The pioneer work of the usability of wearable technologies in heath care is already done. The knowledge should be now transferred to the sports sector.
6. References


