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Scientific/Clinical Article

The fastest field sport in the world: A case report on 3-dimensional printed hurling gloves to help prevent injury

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ABSTRACT

Study Design: Case series.
Introduction: Hand injuries are the most common injury observed in hurling although compliance in wearing protective gloves is reportedly low.
Purpose of the Study: To devise a glove that offers comfort, protection and freedom of movement, using the bespoke capabilities of 3-dimensional (3D) printing.
Methods: Each player's "catching" hand was imaged using a 3D scanner to produce a bespoke glove that they later trialed and provided feedback.
Results: Nine players provided feedback. On average, the players favorably rated the glove for the protection offered. The average response on comfort was poor, and no players reported that glove aided performance during play.
Discussion: This feasibility study explores the versatility of 3D printing as a potential avenue to improve player compliance in wearing protective sportswear. Feedback will help refine glove design for future prototypes.
Conclusions: Hurling is the primary focus in this study, but knowledge gains should be transferable to other sports that have a high incidence of hand injury.
Level of Evidence: 4.

Introduction

Engagement in sport promotes health and well-being but also carries the risk of injury.[1] Hand fractures have been reported as the most common area of injury in sports participation[2] with phalangeal fractures being the most common, particularly to the first and fifth rays.[3] Football (soccer and Gaelic football) is reportedly the sport that presents with the most hand injuries based on data from an Emergency Department in Scotland over a 1-year period.[3] The number of injuries sustained by professional and amateur players was not defined. Injuries to the hand result in the most economic burden and impact on productivity above other injury types.[4]

Sports governed by the Gaelic Athletic Association (GAA) include handball, football, hurling, camogie, and rounders. In Gaelic football, ankle injuries are most prevalent[5,6] although children who participate in Gaelic football more commonly present with hand injuries than lower limb injuries.[7] It has been hypothesized that this is possibly due to the ongoing development of hand-eye coordination in the younger player (collision with the ball was the most common mechanism of injury).

Hurling is a field sport played with wooden sticks and a ball, called hurleys, and a sliotar, respectively. The hurley is used to strike the sliotar on the ground or into the air. The sliotar can also be passed by hand between players. Each team comprises 15 players with the object of accruing goals (weighted as 3 points) under the crossbar of an "H"-shaped goalpost or 1 point over its crossbar.[8] Camogie refers to the female variant of the game. Hurling is thought to pre-date Christianity, and the sport was standardized by the GAA in 1884.[9] It has been coined as the "fastest field sport in the world" due to the high velocity the sliotar can achieve during play.[10] Most hand injuries are sustained from being struck by a hurley.[11] The GAA currently have no regulations on glove requirements for hurling. The need for protection needs to be carefully weighted with the demands of the sport and comfort. In this regard, commercial hurling gloves offer protection to the dorsal aspect of the hand while the palmar area is mainly exposed for sensory feedback when catching the ball. However, compliance of players wearing

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protective gloves is often poor due to impeded performance, discomfort, and excessive perspiration.

Based on a study of 1030 injuries sustained in hurling, most soft tissue injuries occurred in the lower limb, whereas fractures presented more in the upper limb.[12] In a smaller study of 163 adults who participate in hurling, upper limb injuries distal to the wrist were the most observed with 38% of these soft tissue injuries and 68% fractures. Of these, fractures to the fifth and first rays were most common with the highest incidence to the metacarpal, the proximal phalanx, and then the middle phalanx.[13] This reflects similar patterns of injury in another study focusing on hand injuries in hurling.[14] It has been commented that most hurling players do not wear gloves.[13,14] A survey of 163 players shows that it is felt that the bulkiness of gloves results in diminished dexterity essential for handling the sliotar (ball; 75.4%), protection from existing gloves is inadequate (58.3%), and 74.2% of the players would try a newly designed glove if available.[13] Since the mandatory introduction of head and face protection in hurling, associated injuries to these areas have markedly declined although hand injuries remain common place.[11] Although there have been no studies comparing the incidence of hand injuries between players who wear gloves and those who do not in hurling, a study on the variant sports of lacrosse, field hockey, and ice hockey found that there was a significantly higher rate of injury in the ungloved hand.[15]

"Additive manufacturing" (AM), otherwise known as 3-dimensional (3D) printing, technology is increasingly being explored across many fields of science including aerospace and medicine. In its simplest form, 3D printing is a method of building an object layer by layer.[16] There are many different types of AM/3D printing technologies; some extrude plastic filament (similar to a heated glue gun); some are based on "curing" light-sensitive resin using a ultraviolet laser (stereolithography), and others rely on powder-based materials which are either bound together with a high-intensity laser to melt powder particles together (Laser Sintering), or adhesives are deposited to bind the powder (Powder binding). There are many others including PolyJet processes which behave in a similar manner to inkjet printers (but resins are cured with ultra-violet light). Each AM process offers unique strengths and weaknesses, but the view of strength/weakness very much depends on the intended application. One aspect which all processes share is the geometric freedom on offer, and the ability to create almost any 3D form. Given its versatility and ability to create almost anything, AM is ideally suited to making custom-made, custom-fitted artifacts.[17] With regard to hand therapy, there are prior examples of printed wrist orthoses,[18] finger mallet orthoses,[19] and robotic dynamic orthoses for postsurgical rehabilitation.[20] In the context of sports, AM has been used to make custom-made wheelchair gloves for paralympians[21] to improve performance. However, there has been limited development of custom-fitting devices specifically for sports injury prevention.

Purpose

The purpose of this feasibility study was to explore the potential of 3D scanning to produce a bespoke glove for the individual player. The sport analyzed in this instance was hurling. The rationale for this was to address issues associated with poor compliance of hurlers and therefore attempt to design a glove that meets player expectations on comfort, performance, and protection. The intention of this project was to assess the suitability of low-cost 3D printing for making custom-made hurling gloves and to make a range of prototypes for a small cohort in the context of a feasibility study. The findings were intended to establish a means to drive follow-on design specifications and to establish whether 3D printing an entire glove is appropriate, or whether there is a need to mix 3D printing with other fabrication methods to make custom-fitting injury prevention gloves.

The following objectives were set:

- To understand the current requirements of the players in terms of what injury prevention is required;
- To generate quick, low-cost (ie, "low-fidelity") prototypes for review with key stakeholders (mainly, hurling players);
- To generate custom-made sports gloves using 3D printing only;
- To analyze and evaluate a range of key criteria, including comfort, durability, and practicality of using 3D printing as a sole means of fabricating custom-made hurling gloves.

Methods

Ethical approval

This study was conducted in compliance with the Research Governance Framework for Health and Social Care and Good Clinical Practice. It was conducted in accordance with approvals from the Office of Research Ethics Committees in Northern Ireland and the Southern Health and Social Care Trust Research Governance Committee. Ethical approval was also received from the Loughborough University. All participants were given a participant information sheet and provided written, informed consent. Players consented to photographs being taken and used for the purposes of the study.

Study design

This study presents a case series on players who trialed a specially designed 3D-printed hurling gloves to prevent hand injuries. A questionnaire was devised to collect demographic data on each player and to collate their views on the glove. This was completed using a Likert-type questionnaire and open questions.

An iterative design process was followed to develop the glove. This was completed by a hand therapist and industrial designer in academia. The hand therapist had more than 10 year's clinical experience, and the industrial designer was an academic with 8 years experience in AM/3D printing. The hand therapist referred to anatomical considerations, a knowledge of the literature on the most common injuries in hurling, and clinical knowledge of orthotics to aid the process of glove design. The industrial designer was able to advise the therapist on the limitations and possibilities of 3D printing. Together, the hand therapist and industrial designer developed illustrations of how the glove would look and what features would be built into it to allow movement and also offer protection.

There were 2 main phases to the process of creating the gloves themselves: The first process involved capturing participant scan data of their forearm, wrist, and hand. A pilot test of the 3D scanning protocol was performed before capturing participant scan data to check the integrity of the scanning protocol; this was performed by the designer, by capturing the hand therapist's shape of the hand.

The second phase was an iterative cyclical process (see Fig. 1) which involved a number of stages to take concept designs into suitable formats so they could be 3D printed. To print an object on a 3D printer, it is first necessary to make a virtual object using computer-aided design (CAD) software. Therefore, the second phase involved design planning (phase 2.1), CAD modeling (phase 2.2), 3D printing (phase 2.3), evaluation (phase 2.4), and design refinement (phase 2.5).

Three iterations of this process were undertaken to develop initial low-fidelity prototypes into the final designs;