Manufacturing custom-contoured wheelchair seating: a state-of-the-art review

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Summary
This abstract details a state-of-the-art review of the current manufacturing processes used to produce custom-contoured seating systems for wheelchairs. The topic of the abstract fits into the following categories: Research and Service Development.

Aims and objectives
The purpose of this review is to assess the strengths and weaknesses of the current manufacturing methods and materials used in custom-contoured wheelchair seating systems. With this information, alternative means of manufacturing are suggested to resolve existing issues in seating, specifically the high temperatures and moisture levels prevalent with custom foam seating systems that increase the risk of pressure injury in users.

Background
Custom-contoured seating systems were initially developed in the 1960s to accommodate young wheelchair users with cerebral palsy, spina bifida, and other physical disabilities requiring postural support (Watson and Woods, 2005). Today, custom-contoured seating has proved to be key in aiding in the development of motor skills (Green and Nelham, 1991), preventing spinal deformities (Pountney et al., 2002), and in supporting postural stability such that limb mobility and communication are eased in users of all ages (Neville, Quigg and Armstrong, 2005). It is also vital in addressing and preventing pressure injury in full-time wheelchair users. Lowering maximum pressures in weight-bearing areas has been shown to lower the risk of pressure injury (Barbenel, 1991). Custom-contoured seating systems achieve this by enveloping the body and increasing the area over which weight is distributed (Tasker et al., 2014).

However, the majority of custom-contoured seating today is made of foam, an insulator. Thus, the temperature and moisture level at the user-seat interface increases the longer a person is seated in their seating system. High temperatures and moisture levels increase the rate of tissue breakdown, thus increasing the risk of pressure injury development (NPUAP, 2014). Knowing these issues exist in most custom-contoured seating options, further assessment on the strengths and weaknesses of custom-contoured seating and production options was conducted herein.

Technique
This state-of-the-art review was completed through research of current and past literature related to custom-contoured seating and pressure redistribution, as well as through interviews with relevant stakeholders, i.e. custom seating users, occupational therapists, physiotherapists, seating technicians, and others in the custom seating field.

Results and Testing
Five manufacturing methods are currently used to produce custom-contoured seating systems. These are: foam-in-place seating (FIPS), plaster moulding, vacuum forming of moulded seat inserts (MSI), manually-adjustable micro-modular seating (AMMS), and computer numerically controlled (CNC) foam milling.

All of these methods except AMMS produce foam seating, and increased temperatures and moisture levels are issues common to all types of foam custom seating. AMMS seating systems maintain cooler seat and tissue temperatures, but their high rigidity, weight and cost make them

inappropriate for some wheelchair users. Plaster casting using poured foam, the main technique used at Enable Ireland's SeatTech facility, is materially inexpensive but requires high manual labour to produce. CNC foam carving, on the other hand, is highly automated and so needs little to no manual labour, and does not need physical storage space like plaster casting requires. However, it does produce high material waste and has high start-up costs, including the machine and operator training.

Discussion

The major limitations in custom foam seating are high temperatures and moisture levels in the seat, high manual labour requirements, and a need for large amounts of physical storage space. The high temperatures and moisture levels present at the seat surface increase the risk of pressure injury in users, which should be avoided as pressure injury is painful, costly, and can be fatal in some users. The high manual labour requirements and amount of storage space needed to make plaster cast foam seating systems make for an expensive and inefficient manufacturing process. Instead of investing in CNC foam milling, which would lead to an increase in material waste and would not solve the issues of temperature and moisture at the user-seat interface, a new manufacturing route could be developed to produce custom-contoured seating.

Additive manufacturing through 3D printing has already shown promise as an efficient manufacturing process for custom parts, including prototype wheelchair parts and accessories (Hudson, 2016; Smith, 2016). Manufacturing custom seating through 3D printing would minimise the need for physical storage space since the process would use digital storage, like CNC foam milling uses. It would enable more control over the microclimate at the user-seat interface; minimising the foam in a final custom cushion would lower the temperatures experienced by users and lower moisture accumulation at the interface. Although prototypes have shown that 3D printing is capable of making parts of wheelchairs, its feasibility as a manufacturing process for custom-contoured wheelchair seating systems requires further investigation.

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