Analyzing 3D biomechanics of disabled golf athletes; development and validation of a custom made model

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One of the prerequisites of the International Paralympic Committee (IPC) states Paralympic sports should have an evidence based classification system (IPC 2007). The challenges and questions that need to be addressed to develop an evidence based classification system for golf in accordance with IPC regulations have been identified in a review (Stoter et al. submitted 2014). Adjacent, Stoter et al. concluded that timing, accuracy and control, work per joint, range of motion, balance and flexibility are sport specific factors that determine performance in golf. Furthermore, the need to understand the biomechanics involved in handigolf was expressed. To gain insight in the biomechanics of handigolf, a custom made inverse dynamics OpenSim¹ model (3D, 16 segment, 40 Degrees of Freedom) is being developed. The philosophical approach to modeling of Dym (Dym 2006) was followed during development.

1OpenSim is free open-source software, developed at Stanford University (Delp et al. 2007).

![Diagram of Dym's philosophical approach to modeling](Dym_2006_p_7)

Figure 1. Schematic of Dym’s philosophical approach to modeling (Dym 2006, p. 7)

Why: Little is known about the relation between impairments and golf performance. To our knowledge, no model exists capable of analyzing golf biomechanics in relation to impairments. The model that is currently being developed can be virtually amputated at any desirable level.

Find: The measured ground reaction forces and Centre of Pressure, combined with the model’s calculated forces and moments of the joints should provide insight in the biomechanics of the golf swing.

Given: Segment properties such as length, mass and range of motion are based on kinetic data (Dirken 2001, Zatsiorski 2002).

Assume: It is assumed that segments are made of rigid bodies. The foot and forearm-hand combination have been simplified to a single rigid body. The knee joint is represented by a hinge joint.

How: Laws of conservation should apply, mathematical principles involved can be identified.

Predict: The inverse dynamics model predicts joint forces and moments based on ground reaction forces and motion capture data.

Valid: Calculations can confirm whether the physical laws apply. Furthermore, simulated movement of the segments should be physically possible.

Verified: Motion capture data of able-bodied subjects will be used to compare the outcome parameters of our custom model with existing models.

Improve: Further development of the model will allow to conduct forward dynamic simulations as well. Forward dynamic simulations predict movement outcome based on joint forces and moments.

Use: The model below can be used to investigate the biomechanical differences at the joint level (net moments) due to the level of amputation and the consequences for the golf swing, active stability and balance.

Prior to investigating how a lower limb amputation affects the biomechanics of the golf swing, an iterative loop will be implemented (Fig. 1). This loop consists of remodeling, testing, improving and predicting the outcome of the model till the quality and validity of the predictions are satisfactory. Figure 2 shows some preliminary results.

![Graph of Ground reaction forces](GRF_N)

Figure 2. Preliminary results of model kinematics and measured ground reaction forces (GRF) of an able-bodied recreational golf player.


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