ANALYSIS OF THE EFFECT OF TORQUE ADAPTER NUMEROSITY AND STIFFNESS ON THE GOLF SWING IN A RIGHT TRANSTIBIAL AMPUTEE GOLFER

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SUMMARY
The aim of this work was to investigate the effects of three different configurations of torque adapters on the golf swing performance of a right leg transtibial amputee golfer.

INTRODUCTION
In the last years, golf has been spreading to a wider population of amputees, becoming a popular sport. To allow the execution of the swing, specific prosthetic components have to be identified and set-up. To ease this goal, it is necessary to understand the biomechanics of the joints and segments mainly involved. In particular, one of the variables that play a key role is the amount of intra/extrarotation of hips and ankles.

To the authors’ knowledge, only a few studies quantitatively analyzed the lower-limb kinematics in able-bodied during golfing. In addition, only two case studies have been found in the literature involving lower-limb amputees [1, 2]. In the first one, a single torque absorber (TA), allowing a bidirectional maximum rotation of up to 30°, was applied just above the prosthetic foot in a 42-year old male right transtibial (TT) amputee. Three different stiffness values were tested and the only significant difference observed was in the amount of the right leg total extrarotation in the last part of the swing (End of the Follow-Through – EFT). In the second one, a 64-years old male left transfemoral amputee claimed to potentially reduce his personal Handicap up to 4 strokes when using a series of 2 TAs, increasing the amount of rotation. Thus, the aim of this study was to investigate if the use of more than one TA or a less stiff TA could increase the transverse rotation of the subject and the swing quality even in a right TT.

METHODS
Two subjects volunteered for this study. The first one (Amputee) was a 69-years old right TT amputee golfer with a Handicap of 17. The second one (Teacher), was an able-bodied golf teacher and professional with a Handicap of 0. Both subjects were right handed. The amputee used a Variflex LP (Ossur, IS) prosthetic foot, while the TA tested was a 4R85 (Otto-Bock, DE), with maximum allowed intra/extrarotation of ±20°. Three configurations were considered:
1) C1: 2 TAs located along the shank pylon, both with stiffness set to 3 marks (pre-loading scale of the 4R85);
2) C2: same as C1 but with distal TA stiffness set to 16 marks;
3) C3: only one TA placed between the socket and the foot, with stiffness set to 3.

In C1 condition, the amputee performed 5 full golf swings with each of the following clubs: driver, iron 7 and iron 5. Then he performed other 5 swings with the driver in C2 and C3 conditions. The Teacher performed 3 full swings with his own preferred driver.

An optoelectronic system with 6 MX40 cameras operating at 200 Hz (Vicon Motion Systems Ltd, UK) was used for kinematic data collection. Retro-reflective markers were applied to the sound lower limb, pelvis and thorax, according to CAST protocol [3]. 2 additional markers were placed proximally and distally on golf clubs to identify relevant swing events. To describe TAs rotations during swing, a specifically designed measurement protocol was applied [4].

3D trajectories were filtered using the Vicon Woltring routine and lower limb joint kinematics was calculated using self-design software in Matlab R2009b (The MathWorks, Natick, MA). Time was normalized from 0 to 100%, where 0% corresponds to ball address (BA, [5]) and 100% corresponds to EFT [6]. Top of the backswing (TBS, [5]) and ball contact (BC, [5]) were also considered. The X-Factor [7], defined as maximum difference between thorax and pelvis angle in the transverse plane, was calculated as a performance index. The following parameters were calculated to describe feet relative position at BA: distance between right second metatarsal (RSM) and left second metatarsal (LSM) markers (D1); distance between right calcaneus (RCA) and left calcaneus (LCA) markers (D2); angle (FA) between the line joining RCA and RSM and the line joining LCA and LSM.

RESULTS AND DISCUSSION
Results suggested that the most demanding task for TAs are the golf swings performed with the driver (Figure 1). However, the maximum and minimum intra/extrarotation allowed by the TAs were never reached for C1, C2 or C3 (Figure 2). The fact that with a single TA the range was not fully used can be explained by the different posture of the Amputee at BA: in C3, in fact, the amputee increased the FA (i.e. extrarotating the hip) with respect to C1 and C2 (Table 1), and thus “repositioned” the overall range of transverse rotation offered by the TA with respect to the pelvis. Interestingly, the Amputee has the maximum X-Factor among the configurations with C3. In addition, in C3 a lower right ankle extrarotation is reached at EFT with respect to C1 and C2 (Figure 2), which ensures a more physiological, greater right and left hip intrarotation (Table 1) and a visibly lower right foot base of support (Figure 3): it should be noticed that the
Extrarotation at EFT is a side-effect of the TA and is not consistent with the ankle kinematics during swing of able-bodied subjects, which moves instead into plantarflexion.

![Figure 1: Sum of the 2 TAs (C1) rotations for 3 different clubs.](image)

**Figure 1:** Sum of the 2 TAs (C1) rotations for 3 different clubs.

![Figure 2: Sum of the TAs rotation for the conditions C1, C2 and C3.](image)

**Figure 2:** Sum of the TAs rotation for the conditions C1, C2 and C3.

CONCLUSIONS

The use of only one TA (C3 configuration) in the right shank helps carrying out a better swing, since the full rotational range is not reached, the X-factor is maximized and the extrarotation at EFT is minimized, with respect to the configuration in which 2 TAs are used.

REFERENCES


| Table 1: Kinematic data for the Amputee and the Teacher. The club considered is the driver. |
|---------------------------------|----------------|----------------|----------------|----------------|
| **Right Hip extrarotation (°), EFT** | **Amputee** | **Teacher** | **Amputee** | **Teacher** |
| C1 | 39.3 ± 1.6 | 32.1 ± 3.4 | 39.6 ± 1.3 | 15.7 ± 4.0 |
| C2 | 11.9 ± 1.0 | 11.9 ± 2.5 | 15.3 ± 1.6 | 35.9 ± 3.8 |
| C3 | 22.4 ± 0.7 | 23.4 ± 0.8 | 25.1 ± 0.5 | 29.0 ± 3.5 |
| **Left Hip inextrarotation (°), EFT** | C1 | C2 | C3 | Teacher |
| D1 (mm), BA | 27.2 ± 0.8 | 27.4 ± 0.6 | 27.8 ± 1.1 | 45.7 ± 4.0 |
| D2 (mm), BA | 24.0 ± 0.8 | 25.9 ± 1.2 | 24.2 ± 1.0 | 36.7 ± 2.9 |
| FA (°), BA | 29.4 ± 2.8 | 25.4 ± 3.2 | 30.0 ± 2.8 | 25.6 ± 5.0 |