Towards the usage of embedded prosthesis sensors for real-life gait analysis of amputee subjects

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Summary

This case study investigated the potential of the sensors embedded into a mechatronic prosthetic knee joint for clinical gait analysis. The results showed a strong correlation (~ 0.99) and small RMSE between the sagittal knee angle (~1.5%) and knee moment (~7%) recorded during over ground level walking using the gold standard (optoelectronic motion capture) and internal device sensor data.

Introduction

Clinical gait analysis is typically performed in a laboratory environment using optoelectronic motion capture systems and force plates [1]. Due to various limitations of the laboratory assessment (e.g., confined space, constrained pathway), the patient performance is often not representative of real-life gait [1].

To overcome these limitations, researchers have used inertial measurement units (IMUs) to replace optoelectronic motion capture systems and conduct accurate gait analyses in amputee patients outside of a laboratory environment (less than 1° knee angle error) [2]. However, the IMUs are external sensors that have to be placed on the subject and properly aligned to the limb segments. This requires an extra effort and can result in positioning errors that can translate into errors in the recorded movement [3].

Mechatronic lower limb prostheses are equipped with embedded sensors that collect information about orientation, acceleration, angular velocity, joint angles and loads [4]. The validity and potential usage of these sensor data for clinical gait analyses is, however, still unknown. Therefore, there is a need to investigate whether it is possible to accurately measure gait performance using the embedded device sensors, and to compare the performance of these sensors to that of the gold standard of laboratory assessments.

Methods

Kinematic and kinetic data were collected from one patient with transfemoral amputation (height: 169 cm, weight: 76 kg, knee joint: GeniumX3) using a gold standard (GS) motion capture system (Vicon, Oxford, UK) and force plates (Kistler, Winterthur, Switzerland). In addition, the device sensors (DS) were used to assess gait performance. The data recorded by the DS included hydraulic loading and knee joint angle. The data were collected during over ground level walking at comfortable walking speed while simultaneously using both systems (DS and GS).

The sagittal knee angle and moment were determined and the obtained profiles were compared between GS and DS using correlation coefficients, root mean square error (RMSE) and maximum error.

Results and Discussion

The results for a single walking trial are reported in Table 1 and the recorded knee angle profiles are shown in Fig. 1. We found strong correlations between both the knee angle and knee moment acquired by GS and DS (ρ ~0.99).

Further, the RMSE was below 1° for the knee angle and below 5 Nm for the knee moment (1.5% and 7.2% relative error, respectively). The maximum error was 3.27° and 7.41Nm, respectively. These results demonstrate that the embedded sensors can measure sagittal knee angles with a similar quality as the wearable inertial measurement units [2].

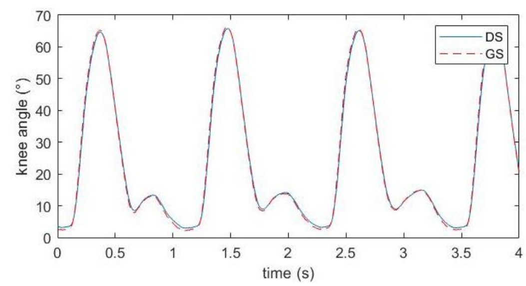

Figure 1: The knee angle recorded using device sensors (DS, continuous line) versus gold standard (GS, dashed line).

Table 1: Error and correlation between device sensors (DS) and gold standard (GS).

	RMSE	Max. Error	Correlation Coefficient (ρ)
Knee Angle (°)	0.95	3.27	0.99
Knee Moment (Nm)	4.26	7.41	0.99

Conclusions

The preliminary results show the potential of embedded prosthesis sensors to assess knee angle and moments during amputee walking. A limitation is that this analysis only focuses on the affected limb. Additional experiments with other prosthesis sensors and more activities of daily living such as ramp and stair incline and decline, as well as a larger patient sample need to be conducted.

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References

[1] Cutti, A. et al. (2015) *G Ital Med Lav Ergon* **37**: 45-8.
[2] Seel T. et al. (2014) *Sensors* **14**: 6891–909.
[3] Bolink S. et al. (2016) *Med Eng Physics* **38**:225–31.
[4] Bellmann M. et al. (2019) *Biomed Eng* **64**:407–20