# Automatic Versus Manual Tuning of Robot-Assisted Gait Training

**C. Bayón, S. S. Fricke, H. van der Kooij, and E. H. F. van Asseldonk**

**Abstract** Robot-assisted gait training (RAGT) is a promising rehabilitation technique that is increasingly used in the clinic to improve walking ability after a neurological disorder. The effectiveness of RAGT might depend on the customization of the robotic therapy, which in most of the cases is done either manually by the clinical practitioner (MT) or by adaptive controllers developed to automatically adjust the assistance (AT). In this contribution we present a comparison of automatic versus manual tuning of RAGT, where we assessed the differences in the adjustment of the therapy for ten participants with neurological disorders (six stroke, four spinal cord injury). The AT approach reached stable assistance levels quicker than the MT approach. Moreover, the AT ensured a good performance for all subtasks of walking with lower assistance levels than the MT. Future clinical trials need to be performed to show whether these apparent advantages result in better clinical outcomes.

## 1 Introduction

In clinical practice, robot-assisted gait training (RAGT) is used to provide intensive, repetitive and task-specific training, while it also contributes to reduce physical load for therapists [1]. The amount of robotic assistance provided during RAGT is frequently manually chosen by the practitioner (MT). This leads to outcomes that can be influenced by subjective decisions, and assistance tuning may become a time-consuming task. In the last years, automatic algorithms have been developed with the aim to objectively and quickly tune the assistance (AT) and properly tailor the therapy to patient's capabilities [2, 3]. In this contribution we present the main results

C. Bayón and S. S. Fricke are contributed equally to the presented work. First author is shared between C. Bayón and S. S. Fricke.

C. Bayón (✉) · S. S. Fricke · H. van der Kooij · E. H. F. van Asseldonk
Department of Biomechanical Engineering, University of Twente, Enschede, The Netherlands
e-mail: c.bayoncalderon@utwente.nl



D. Torricelli et al. (eds.), *Converging Clinical and Engineering Research on Neurorehabilitation IV*, Biosystems & Biorobotics 28,
https://doi.org/10.1007/978-3-030-70316-5_2

of an exploratory study [4] where we compare the MT and AT approaches by using the LOPES II gait trainer.

## 2 Materials and Methods

### *2.1 Robotic Device*

The LOPES II gait trainer is a treadmill-based rehabilitation device with eight actuated degrees of freedom for the hips, knees and pelvis to guide the lower limbs following prescribed gait patterns. The robotic assistance provided by the device can be classified into seven subtasks of walking (i.e. weight shift, lateral foot placement, leading limb angle, trailing limb angle, prepositioning, stability during stance and foot clearance). For each of those subtasks, the assistance can be tuned from 0 to 100%.

### *2.2 Tuning of the Robotic Assistance*

In both approaches (MT and AT) the subtask-based assistance could be adjusted individually and separately for each leg in steps of 10%.

For the MT, an intuitive user interface was used by an experienced therapist. The subtasks could be coupled or decoupled for the adjustments, allowing simultaneous changes in assistance for the coupled subtasks. Visual feedback about the user's performance with respect to the reference gait pattern was provided for each subtask to the physical therapist.

For the AT, the algorithm described in [2] was used. It tuned the assistance by evaluating deviations of the measured joint angles from the reference pattern at specific key points of the gait cycle (e.g. max. knee flexion). Each key point corresponded to one particular subtask of walking.

### *2.3 Experimental Protocol*

Six stroke survivors (STR) and four persons with incomplete spinal cord injury (SCI), all in chronic phase (>6 months after injury), took part in this study. Experiments were approved by the local ethical committee (METC Twente), and participants gave written informed consent prior participation.

The experiment consisted of two sessions: familiarization and experimental session. The familiarization session was used to practice walking in the LOPES II and to set the preferred walking speed and partial body weight support (PBWS)

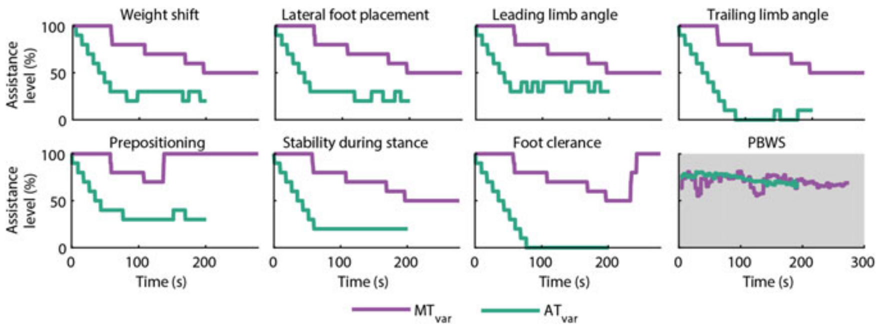


**Fig. 1** Subtask-based assistance tuning for the most impaired leg of one of the SCI subjects in $MT_{var}$ and $AT_{var}$ trials. PBWS was not tuned, but measured, and it varied due to the use of handrails

for each participant. In the experimental session, these parameters were used while assessing the MT and AT approaches in four trials: $MT_{var}$, $MT_{const}$, $AT_{var}$ and $AT_{const}$. For the "var" trials, the assistances were tuned for each subtask, either by the physical therapist ($MT_{var}$) or by the automatic algorithm ($AT_{var}$). For the "const" trials, the robotic assistances were kept constant at the levels found during the tuning, and the participants walked for 3 min with these levels.

### 2.4 *Assessment*

To analyze differences between the MT and AT approach, we focused on several aspects: time to reach stable assistance levels (difference to final level <10% for all subtasks), final amount of assistance, errors with respect to the reference pattern at final amount of assistance, and participants' preferences.

## 3 Results

On average, a stable assistance level was reached more quickly for $AT_{var}$ (110 ± 54 s) than for $MT_{var}$ (279 ± 120 s). Figure 1 shows as an example how the robotic assistance was tuned for the different subtasks in $AT_{var}$ and $MT_{var}$, for one of the SCI participants.

The amount of final robotic assistance was higher for the MT approach than for the AT approach in 53 of 70 cases (70 cases = 7 subtasks · 10 participants), see Fig. 2 as an example. Remarkably, although often less assistance was applied for $AT_{const}$ than for $MT_{const}$, the largest errors of up to 20° of deviation from the reference trajectory were found for $MT_{const}$ (Fig. 2).

Participants did not report any clear preference of one approach over the other regarding safety, comfort, effect and amount of assistance.

## 4 Discussion and Conclusion

The AT approach had several advantages compared to the MT approach, from which we highlight: (1) quicker tuning to stable assistance levels, (2) lower assistance levels reached, (3) good performance for all subtasks with respect to reference patterns. This AT algorithm [2] may be easily transferred to other robotic trainers that use kinematic references in their control.

The therapist often provided higher assistances than the AT algorithm, which could mean that the MT approach is not that good in enhancing the active participation of the patient. One of the reasons for that might be that the therapist acted on the safe side, by trying to prevent possible problems as stumbling or exhaustion. Although he could use the user interface to see the participant's performance respect to the reference trajectories for all subtasks, he mainly relied on visual assessment of the gait pattern when tuning the assistance. This could be an indication that the therapist tried to reach an acceptable walking pattern rather than to decrease deviations from reference trajectories.

Although it is not known which combination would work best, we believe that a combination of AT and MT subtask-based assistance could be beneficial for future RAGT as it would take into account therapist's knowledge but also the advantages of the AT algorithm.

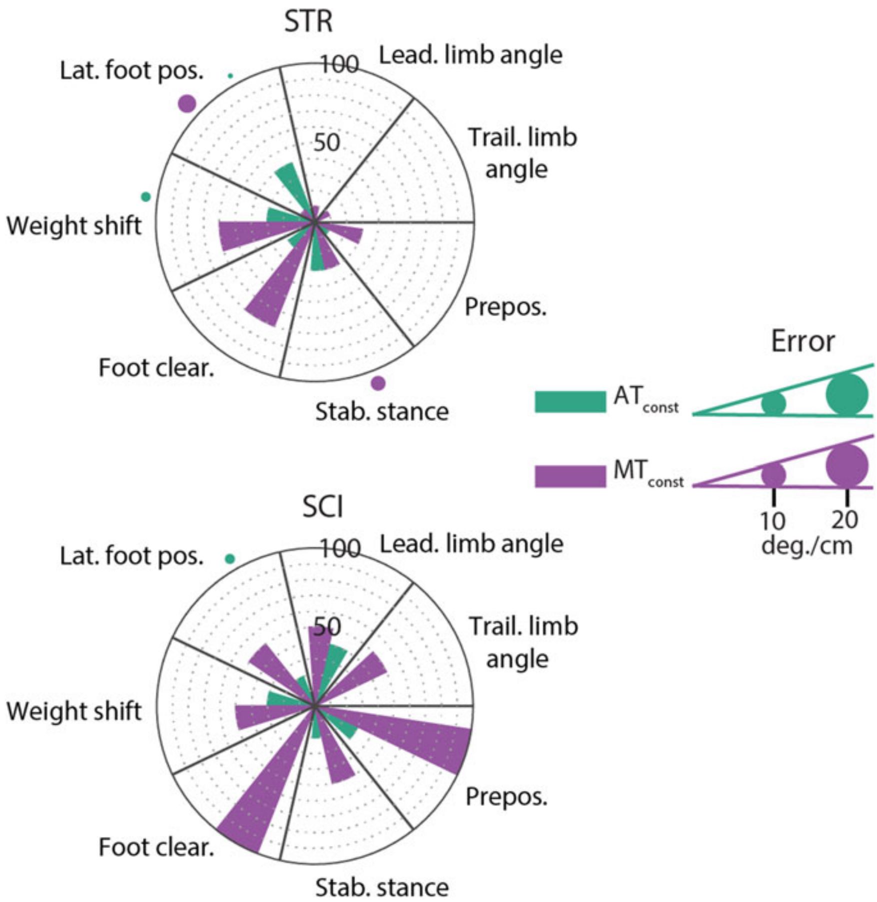


**Fig. 2** Assistances (bars) and errors (circles) for all subtasks with respect to the reference pattern in the more impaired leg for one STR and one SCI subjects, in $MT_{const}$ and $AT_{const}$

**Acknowledgements** This work was supported by the Dutch NWO Domain Applied and Engineering Sciences, project number 12850 (AWARD project).

## References

1. M.R. Spiess, F. Steenbrink, A. Esquenazi, Getting the best out of advanced rehabilitation technology for the lower limbs: minding motor learning principles. PM R **10**(9), S165–S173 (2018)
2. C. Bayón, S. Fricke, E. Rocon, H. van der Kooij, E. van Asseldonk, Performance-based adaptive assistance for diverse subtasks of walking in a robotic gait trainer: description of a new

controller and preliminary results, in IEEE International Conference on Biomedical Robotics and Biomechatronics (BioRob) (2018)
3. S. Maggioni, N. Reinert, L. Lünenburger, A. Melendez-Calderon, An adaptive and hybrid end-point/joint impedance controller for lower limb exoskeletons. Front. Robot. AI **5** (2018)
4. S.S. Fricke, C. Bayón, H. Van Der Kooij, E.H. Edwin, Automatic versus manual tuning of robot-assisted gait training in people with neurological disorders. J. Neuroeng. Rehabil. **17**(1), 1–15 (2020)