Design and Application of Vibrotactile Feedback to Influence Gait Symmetry

Naef AC[1,2,†], Legrand ML[1,2,†], Jungi Z[1], Gassert R[2], Lambercy O[2], Awai CE[1]

1 *Data Analytics & Rehabilitation Technology (DART), Lake Lucerne Institute, Vitznau, Switzerland*
2 *Rehabilitation Engineering Laboratory, ETH Zurich, Zurich, Switzerland*
† *These authors contributed equally and share first authorship*

INTRODUCTION

Recovering gait is crucial for improving independence and quality of life after neurological injuries.[1,2] Conventional gait therapies are beneficial; however, motor learning is often hindered as feedback is only verbal.[3]

Real-time biofeedback, defined here as the addition of an external stimulus delivered on the basis of motor performance, has the potential to enhance motor learning and personalize training.[4,5] Visual feedback has been shown, via 21.7-point decrease in the Gait Deviation Index, to induce changes in stance time symmetry ratio and overall gait.[6]

The goal of this study was, similarly, to explore the evolution of the stance time symmetry ratio between natural walking and walking with vibrotactile feedback.

METHOD

Experimental Setup

Haptic design: (Fig. 1)

- Elitac Wearable Science Suit
- Tactor locations: ankle, knee, hip
- Attachment side: Left
- Motors: Eccentric Rotating Mass

- Vibration duration: Fixed 0.4s
  Longer duration = further from target
- Start: at left toe off, detected via real-time motion capture (Vicon)

- Vibration interpretation for stance time:
  Properly achieved (±5%) = knee
  Too high = hip
  Too low = ankle
- Feedback type: terminal

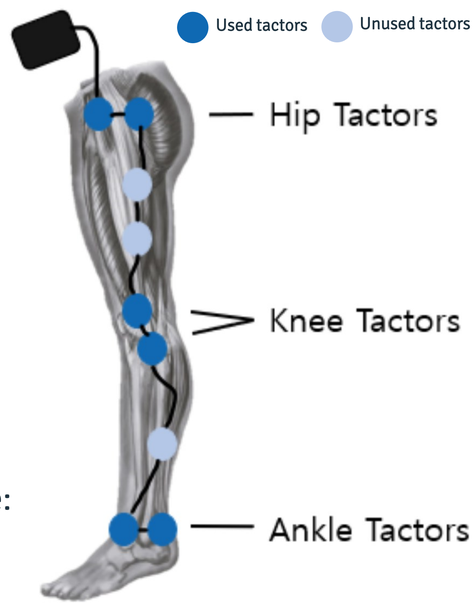


Fig. 1. Schematic outlining the tactor locations.

Participants were instructed to reduce their gait symmetry to approximately 80%, simulating a mild asymmetry.

SR = (left gait parameter value)/(right gait parameter value)

SR, symmetry ratio; gait parameter value, value of specific gait parameter calculated each gait cycle

Target value of the gait parameter is computed at each step

$$Target = 0.8 \times BSR \times \left(\frac{right_0 + right_{-1} + right_{-2}}{3}\right)$$

Target, target value for the gait parameter of interest on the left side (defined here as side of interest); BSR, baseline symmetry ratio of the gait parameter of interest; right0, right-1, and right-2, right parameter value in the current, last, and second last gait cycle, respectively, of the right foot

The calculated target value is compared with the value of the current step and vibrotactile biofeedback is given.

Additional gait parameters were calculated to evaluate how changes in a single parameter can influence others. This was examined via the gait deviation index and Spearman's rank correlations.

Trial Design (Fig. 2)

Block	Baseline	Feedback Phase				
		Natural Walking	FB	No FB	FB	No FB
Time (min)	5	1	3	1	3	3
Speed	100% PGV	80% PGV				

Fig. 2. Schematic outlining the experimental protocol. Abbreviations: FB, feedback; No FB, no feedback; Min, minutes; PGV, preferred gait velocity.

Feedback blocks: react and modify gait according to the vibrations
No feedback blocks: try to retain the altered gait patterns without inputs

RESULTS

15 neurologically intact participants
7 females, 8 males; 35 ± 13.8 years

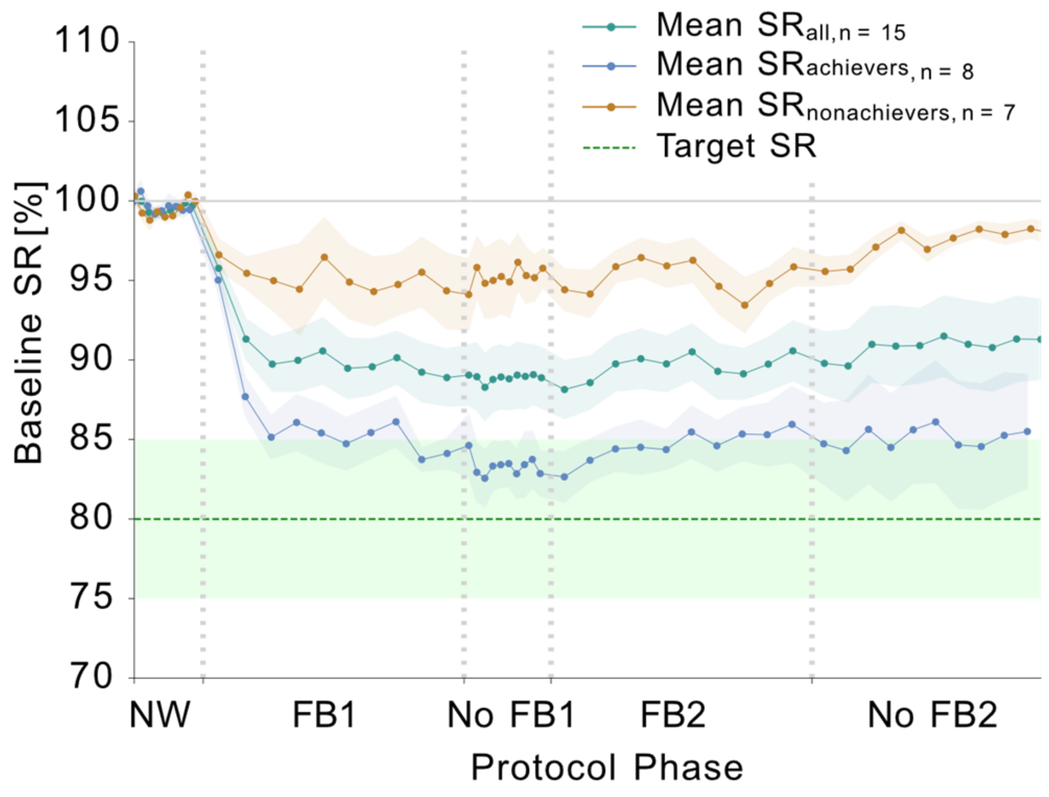


Fig. 3. Evolution of stance time symmetry ratio. Mean symmetry ratio of all participants and the split into achievers (blue) and non-achievers (orange). Abbreviations: FB, feedback; No FB, no feedback; NW, natural walking; SR, symmetry ratio.

Participants could use biofeedback to adapt their gait, but almost half did not reach the target asymmetry range (Fig. 3)

Average Gait Deviation Index decrease of 12.8 points

- Suggests overall changes to gait are induced when a single gait parameter is targeted

Fair correlations observed between the symmetry ratios of:

- Stance time and push-off force (r = 0.45)
- Stance time and vertical ground reaction force (r = 0.40)
- Suggests there is a relationship between temporal and kinetic gait parameters

CONCLUSION

- Terminal vibrotactile biofeedback was able to influence gait symmetry in neurologically intact individuals
- Changes in stance time symmetry ratio did not occur in isolation
- Biofeedback targeting a single gait parameter will most certainly also influence gait as a whole

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chris.awai@llui.org