Motor retraining by real-time sonic feedback: understanding strategies of low impact running (PhD Academy Award)

Pieter Van den Berghe

1. Department of Rehabilitation Sciences, Ghent University, 9000 Gent, Belgium
2. Department of Movement and Sports Sciences, Ghent University, 9000 Gent, Belgium

CONTACT DETAILS:
Pieter Van den Berghe (pieter.vandenberghe@ugent.be)

Department of Movement and Sports Sciences, Ghent University, Gent, Belgium

Sport Science Laboratory - Jacques Rogge, Watersportlaan 2, 9000, Gent, Belgium
WHAT DID I DO?
The aims of this thesis were to (1) develop, (2) to validate a wearable system for impact reduction through the use of real-time, music-based biofeedback, (3) to evaluate its effectiveness in a gait retraining context, and to gain insight into possible strategies for low impact running.

WHY DID I DO IT?
Altering running technique by gait retraining may help to manage injury risk in distance running. So far, gait retraining with the use of real-time feedback on impact loading has been conducted or evaluated in a biomechanics laboratory. My work intended to transfer both the practice and the evaluation out of the lab and into an ecologically valid context. Further, I wanted to advance the understanding of how impacts are affected by running technique.

HOW DID I DO IT?
Experiments were designed to develop and test an auditory biofeedback system that provided perceptible music-based feedback in real-time. The first five studies focused on the measurement of peak tibial acceleration (PTA) as a real-time measure of impact loading, the design of a feedback strategy that distorts music at high PTA, the development of smart running accessories, and evaluating the effectiveness of the biofeedback system for impact reduction in a training centre. I let runners individually explore and learn, on the basis of instantaneous biofeedback, to adapt a running style with lower impact loading. Additional empirical research was undertaken to better understand motor strategies that might lower PTA. Studies six through nine were designed to improve our understanding of impact loading in over-ground level running.

WHAT DID I FIND?
The main findings of the nine original studies:

1) PTAs were reliable within and between sessions, correlated to the maximum vertical loading rate of the ground reaction force, and changed as the speed changed during level running [1].
2) Perceptible auditory biofeedback can consist of pink noise superimposed on tempo-synchronized music [2].
3) PTA decreased (-27%, -2.96 g) without significantly changing the running cadence in a single session of 20-min running with the music-based biofeedback system [3].
4) The major change in PTA occurred after approximately eight minutes, though the time to the major reduction varied considerably between participants [4].
5) PTA decreased (-26%, -2.77 g) in the experimental group and did not change significantly in the control group at the end of a three-week running program [5]. We found no group differences in running cadence between the start and the end of the running program.
6) In a large group of rearfoot strikers, runners demonstrating a greater strike index generally had a greater PTA and greater maximum vertical loading rate [6].
A pronounced rearfoot strike partially explained the remarkably low vertical loading rate of a long-distance runner who completed 100 marathons in 100 days [7].

The three-dimensional resultant PTA was greater in non-rearfoot strikes compared to rearfoot strikes, which was due to a greater fore-after tibial acceleration reflecting a more sudden decrease of the forward momentum of the lower leg following touchdown [8].

Time-force waveforms of the vertical ground reaction force of two subjects suggest that different motor strategies exist to diminish PTA of high impact runners. Concerning the footstrike pattern, a rearfoot striker adopted a more pronounced rearfoot strike, that is, a smaller strike index accompanied by a long foot-ground contact. The second motor strategy involved a change in non-rearfoot striking as the impact peak was visually absent, which is commonly seen in mid-to-forefoot strike patterns.

WHAT IS THE MOST IMPORTANT CLINICAL IMPACT / PRACTICAL APPLICATION?

- This approach led to a wearable biofeedback device that is operable in an ecologically valid setting (Figure 1). The real-time auditory feedback on PTA is useful to reduce impact loading (ie, axial PTA) out of the lab.

- This reduction is not necessarily achieved by increasing running cadence and does not coincide with exposure time among subjects, which points to a motorically heterogeneous response. Distal kinematics affect three-dimensional PTAs and, therefore, play a prominent role in impact modification.

- Different motor adaptations can occur and warrant caution for practitioners and researchers who are making use of biofeedback on PTA. The associated shift in musculoskeletal load when engaging in gait retraining for impact reduction may have implications for running-related injury risks.

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REFERENCES


FIGURE CAPTIONS

A

B

The mean change in peak tibial acceleration was -27% and -26% in studies 3 and 5

C
Figure 1

A: The author wearing the music-based biofeedback device outdoors. A lightweight accelerometer is embedded in a compression sleeve worn on the lower leg and communicates wirelessly with the processing unit hidden in a slim trail running backpack. B: Illustrative scheme of the biofeedback system. The peaks of the axial tibial acceleration are detected step-by-step. The time between PTAs is used to synchronize the beats of the music to the steps of the user in real time. Noise is superimposed if the PTA is high. Studies 3 and 5 evaluated the effect of the biofeedback on running cadence. C: Potential strategies of low(er) impact running are examined in studies 6 to 9 with the use of motion capture, ground reaction force and plantar pressure data.