

How long does it take to adjust steps after an unexpected perturbation during running?

Mikaël Scohier, Dominique De Jaeger, Bénédicte Schepens

*Laboratoire de physiologie et biomécanique de la locomotion, IoNS,
Université catholique de Louvain, Louvain-la-Neuve, Belgium*

INTRODUCTION: The mechanism of running can be modelled as a simple spring-mass system bouncing on the ground, with a single spring representing the runner's leg and a point mass equivalent to body mass.

When the conditions of running are modified, for example by changing surface stiffness [1] or running barefoot compared to shod [2], it has been shown that runners adjusted their leg stiffness.

We applied an unexpected dorsoflexion to the ankle just before the foot contact during running. We observed some immediate biomechanical adjustments, including a decreased leg stiffness and a decreased and delayed foot-slap (unpublished results). We are now interested in quantifying the long-lasting effect of the perturbation: Is the next step still affected by?

METHODS: Four male subjects (27.3 ± 2.0 years, 77.4 ± 12.3 kg, 182.6 ± 2.6 cm) ran at 2.8 m.s^{-1} on a treadmill. A new experimental portable device, inspired by that of Andersen and Sinkjær [3], was designed to deliver a well-defined perturbation to the right ankle joint at a precise moment while the subject is running on a treadmill. This apparatus consists of two carbon fibre shells which hold the foot and the lower leg. These shells are linked by a hinged joint pivoting at the centre of rotation of the ankle and allowing only dorso-plantar movements. A clutch connected to a servomotor by a cable is capable of flexing the foot at a maximal speed of 600 deg.s^{-1} and a maximal torque of 300 N.m. This clutch can be activated at any predetermined moment of the stride. The whole device weights less than 1 kg.

During the experiments, the ground reaction forces were measured by 4 force transducers mounted under the treadmill (1kHz sampling). The angular position of the ankle was measured with an optical encoder incorporated in the ankle device (1kHz sampling). We unexpectedly provoked a dorsoflexion of the right ankle 42 ± 14 ms ($n = 88$) before the right foot contact during running and provoked an accented dorsoflexion of the right ankle at the time of foot contact. Here we analyze the effects on the following left step.

RESULTS: At the time of foot contact, the right ankle is 5.5 ± 2.3 deg ($p < 0.0001$) more in dorsoflexion. This perturbation affects the following left step by a significant increase of the leg stiffness in 2 of the 4 subjects, but with a unmodified foot slap in amplitude and timing. The left step period as well as the left step contact period were unmodified.

CONCLUSIONS: We have already shown (unpublished results) that an unexpected perturbation of the right ankle just before the right foot contact during running affects that right step (in our 4 subjects), including a decreased leg stiffness with a decrease and a delay of the foot-slap, even if the right step period was not modified. Here, we show that this also affects the following left step but in a lesser extend. We observe an increased leg stiffness only in 2 of the 4 subjects and no change in the foot-slap or in the left step period. In conclusion there seems to be a progressive return to normal running.

REFERENCES

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