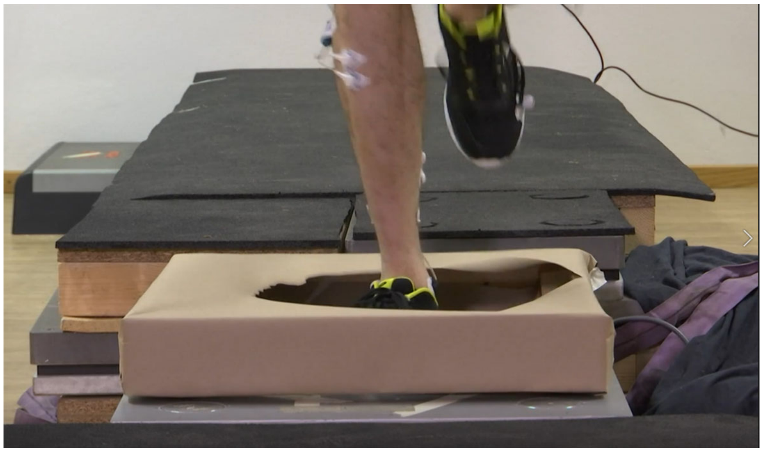
INSIDE JEB

# Pivot point keeps walkers upright when they stumble



One of the walkers after stepping on the disguised curb. Photo credit: The Multimedia Centre, Friedrich-Schiller-University.

We've all done it – stumbled after misjudging our step off a curb. Fortunately, most of us successfully take these jarring tumbles in our stride. Roy Müller, from Klinikum Bayreuth GmbH and Friedrich-Schiller-University, Germany, was curious about how people manage to maintain their balance without missing a step. Johanna Vielemeyer, also from Klinikum Bayreuth GmbH and Friedrich-Schiller-University, explains that our whole bodies essentially pivot around a point as we stride from one foot to the next on the flat; so long as this pivot point remains above the body's centre of mass, it helps us to stay upright. But Vielemeyer, Eric Grießbach (from Friedrich-Schiller-University) and Müller wondered what happens to this dependable stabilising pivot when wrong-footed walkers try to recover their balance. Does the pivot point vanish all together as we wobble around?; does it dip below the essential centre of mass, making us more unstable?; or does it fluctuate briefly as the foot jars down and the walker endeavours to remain upright?

Intrigued, the trio recruited 11 walkers who were prepared to be deliberately wrong footed. Initially, they constructed a walkway with a 10 cm curb that would allow them to measure the forces exerted on the ground as the walkers stepped down; then they calculated the forces exerted back on the walkers by the ground and superimposed them. The forces intersected to reveal that the point about which the body pivoted during a controlled descent down the curb was located above the walker's centre of mass.

Vielemeyer and colleagues then tried to unbalance the volunteers by disguising the location of the curb. Wrapping a 10 cm high block of wood in brown paper, the team laid it in line with the higher walkway and asked the walkers to step down from it, in much the same way that they had from the original curb. However, on some occasions, the scientists cunningly removed the wooden block, replacing it with the empty paper wrapping, which collapsed when the walkers stepped on it, causing them to stumble. 'There were two behaviour patterns; about one-half did not mind … they simply continued to walk normally', says Vielemeyer. However, the remaining participants were quite disturbed when their foot crashed through the paper: '[they] raised their arms quickly to compensate while "falling" the additional 10 cm', Vielemeyer recalls.

The team then recalculated the forces exerted by the ground as the walkers negotiated the collapsing curb, superimposed them, and saw that, again, they crossed. The pivot point remained positioned above each walker's centre of mass to maintain their stability. 'If the pivot point is above the centre of mass, it means that we are suspended like a pendulum while walking', says Vielemeyer. So, our bodies swing back naturally – like a pendulum – repositioning our centre of mass beneath the pivot point when we stumble unexpectedly. However, the trio noticed that the superimposed forces no longer crossed at one tight spot as they had when stepping down from a solid curb. Instead, the crossing point was spread out. 'The forces oscillate more around the expected position of the pivot point', says Vielemeyer.

So, walkers seem to take stumbles in their stride by using the same strategy that keeps them stable on the flat, and Vielemeyer suggests that the same approach could be programmed into bipedal robots to help them to remain upright when wrong footed.

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**Vielemeyer, J., Grießbach, E. and Müller, R.** (2019). Ground reaction forces intersect above the center of mass even when walking down visible and camouflaged curbs. *J. Exp. Biol.* **222**, jeb204305. doi:10.1242/jeb.204305

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