Vertical ground reaction forces determination under individual foot on instrumented treadmill

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The quantification of the vertical ground reaction force (vGRF) acting under each individual foot when walking on an instrumented treadmill is required for many aspects of gait analysis.

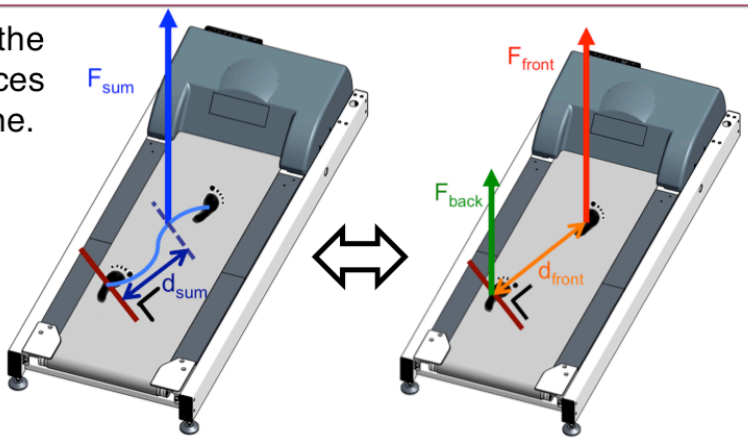
While instrumented treadmills decrease the time and lab space requirements compared to fixed force plates, single- and split-belt technologies compete in their ability to induce natural gait and determine single foot forces during the double contact phase (DC) of walking.

A single belt treadmill typically measures only the sum of all vGRFs acting on the treadmill (F_{sum}). During the DC, the vGRF acting upon the back limb (F_{back}) and the front limb (F_{front}) can be determined using simple mathematical concepts.

Individual vGRF are determined using the equations of equivalence of the vertical forces and of the moments around an horizontal plane.

$$F_{front} \times d_{front} = F_{sum} \times d_{sum}$$

$$F_{back} = F_{sum} - F_{front}$$



The limits of the DC are determined by the abrupt variations of the distance covered by the centre of pressure (Meurisse et al., 2016).

297 steps from 11 subjects (5 women and 6 men; age: 27 to 55 y) were collected while walking at speeds ranging from 0.56 to 1.94 m.s^{-1}.

The vGRF recorded with a gaitway treadmill (F_{real}) under the front and the back foot were compared with the vGRF determined ($F_{determined}$) from the total vGRF.

d_{sum} is the lever arm of F_{sum} relative to an axis perpendicular to the line joining the two feet.

d_{front} is the distance between F_{back} and F_{front} and it is set as a constant during the DC.

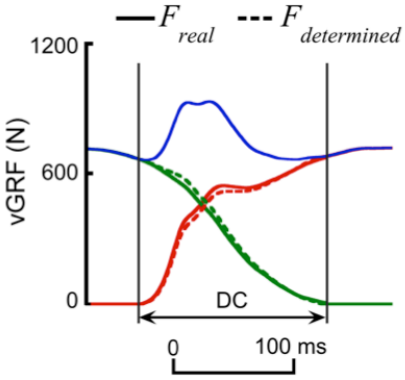
The mean error on vGRF is of **2.25 ± 0.74%** in normal walking at speeds of 0.56 to 1.94 m.s^{-1}.

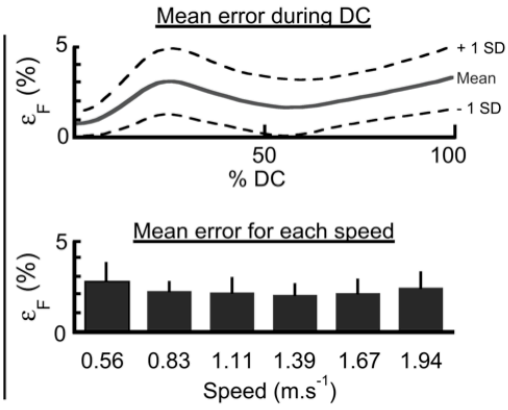
The mean error (ε_F) is independent of the walking speed and is equivalent to 2 % of the body weight.

The unique approximation done in the computation is using a fixed value of d_{front} during the DC.

$$\varepsilon_F(\%) = \frac{|F_{determined} - F_{real}|}{F_{max}}$$

F_{max} is the maximum of F_{back} during DC.





This method of individual foot vertical ground reaction forces determination:

- avoids the complications related to a split-belt treadmill
- allows subjects to walk naturally without constraint on the foot position on the belt
- requires no mathematical interpolation nor estimation

It is useful, for example

- to analyze gait asymmetry
- to analyze, body weight transfer from one leg to the other
- to overlay the force vector on kinematic video while walking on a treadmill

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