HOW DO HUMANS ACCELERATE WHILE RUNNING?

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INTRODUCTION

Accelerated running requires a positive fore-after net impulse. This can theoretically be realized in 3 (non-exclusive) ways (see figure 1):
1/ reduce duration of braking GRF (= earlier zero-crossing)
2/ reduce amplitude of braking GRF
3/ increase amplitude of accelerating GRF
We test how humans actually accelerate over a wide range of accelerations.

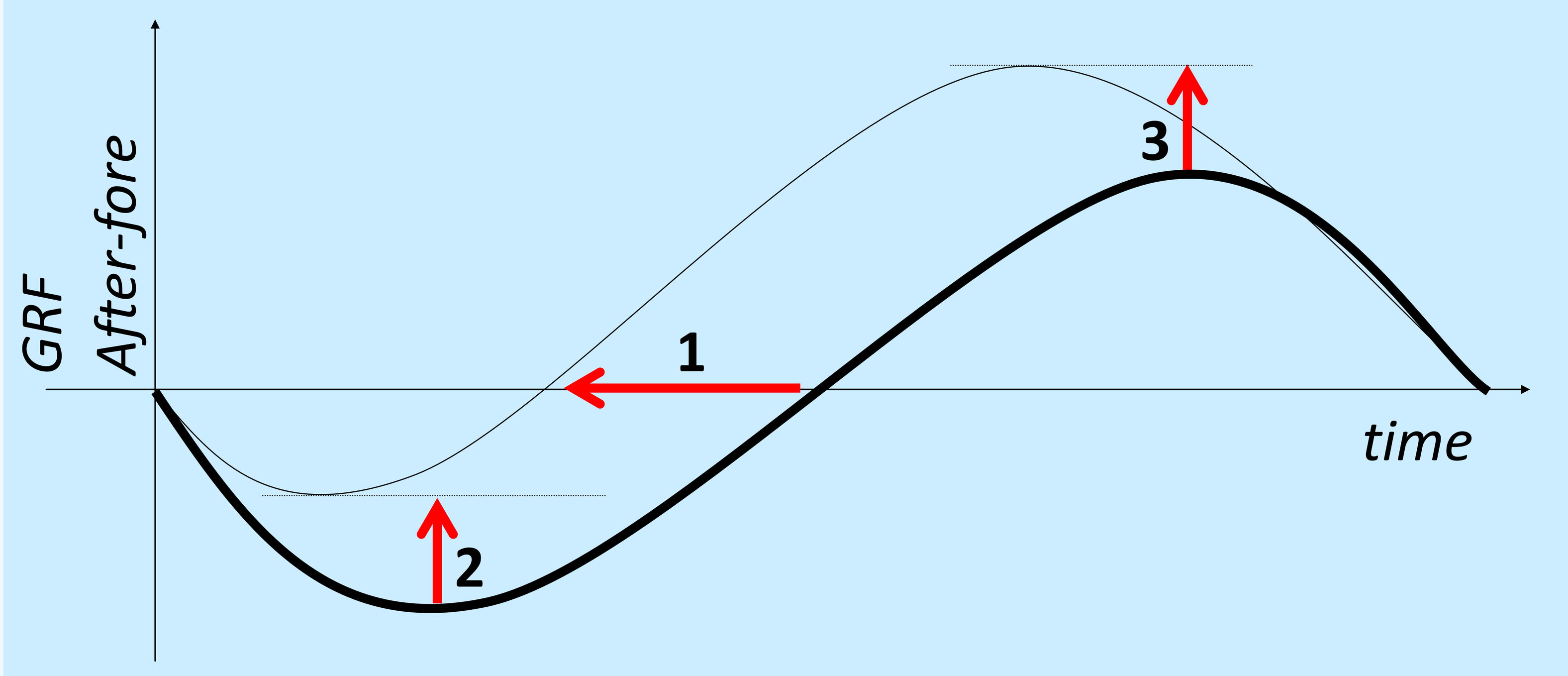

Figure 1: Strategies to modulate braking and accelerating impulse.

METHODS

13 subjects (6M, 7F; 72.6±9.2kg) accelerate spontaneously (-2.7 to 4.5m.s^{-2}) overground.
131 (±34) footfalls/subject registered by means of 4 force plates (1000Hz).
Negative (I_{neg}) and positive (I_{pos}) impuls and relative zero-crossing calculated for each step and regressed against acceleration.
All regressions except for F_{neg} significant ($p<0.001$).
Slopes of mean regressions compared using paired samples T-tests (* $p<0.001$, ^{t} $p<0.1$).

RESULTS & DISCUSSION

Based on criterium (I_{neg}> -0.10N.s.kg^{-1}, [1]): sprint-alike stances vs running stances (figure 2).
When I_{neg}< -0.10N.s.kg^{-1} : Running stances occur until 1.27m.s^{-2} (±0.43).
When I_{neg}> -0.10N.s.kg^{-1} : Sprint alike stances appear from 0.34m.s^{-2} (±0.28).
Between 0.34m.s^{-2} and 1.27m.s^{-2} : At low accelerations, subjects can use a running and sprint-alike pattern.

Submaximal accelerated running stances:
- decrease I_{neg} > increase I_{pos} (*)
- Increase amplitude F_{pos} (=Kugler [2]) = decrease amplitude F_{neg} (<=> Roberts [3]: decrease amplitude F_{neg} less important than increase amplitude F_{pos})
- Earlier zero-crossing (=accelerated walking, Orendurff [4]) further supports imbalance + explains why I_{neg} most determines acceleration.

Sprint-alike running stances:
- Increase I_{pos} > decrease I_{neg} (= Hunter [1]) (*)
- Increase I_{pos} (> than running) (*)
- Decrease I_{neg} (< than running) (*)
- Increasing F_{pos} (> than running) (*)
- Constant F_{neg}
- Earlier zero-crossing (> than running) (*).

Submaximal decelerated running stances:
Similar, but inverse pattern than for submaximal accelerated running.

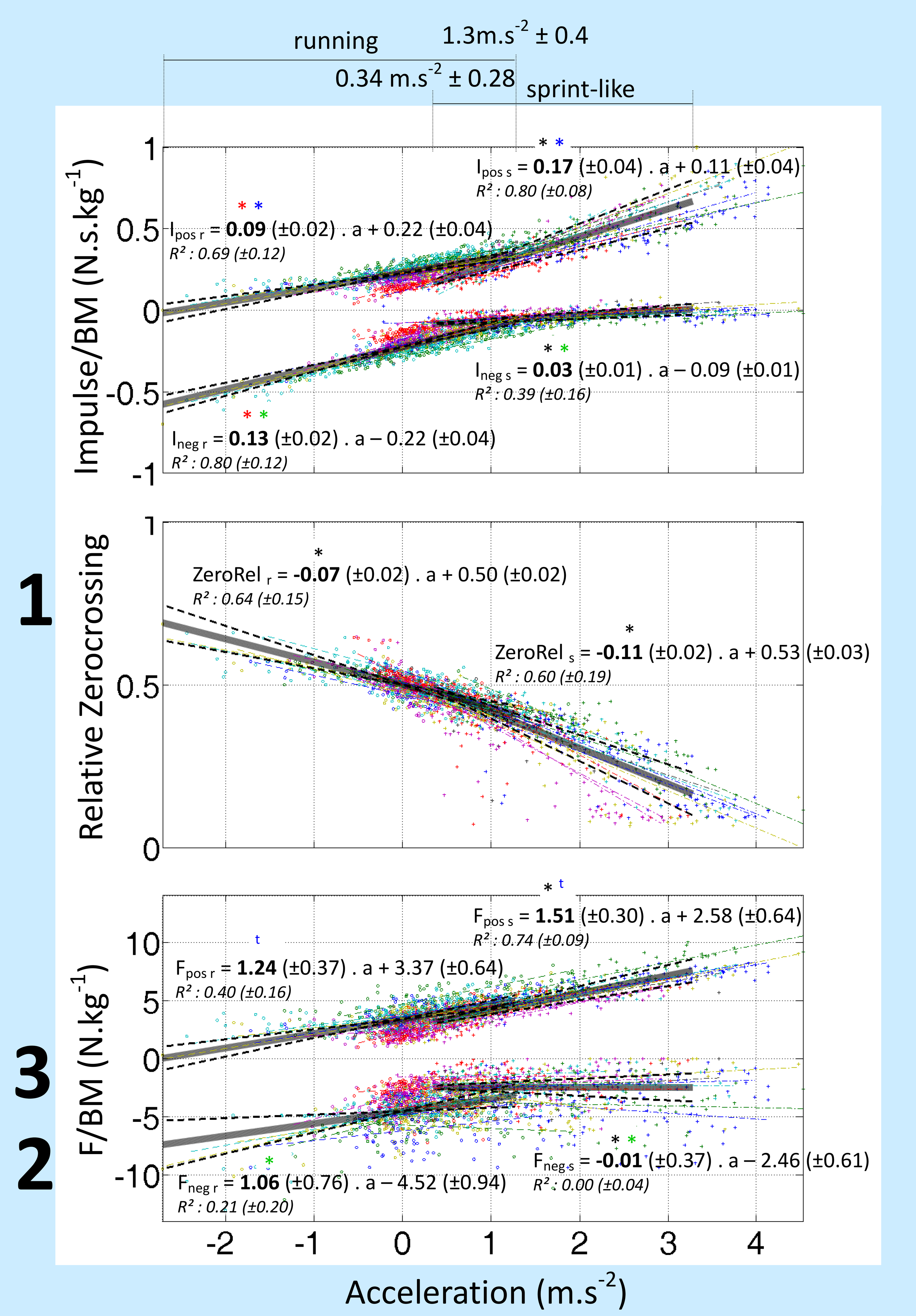

Figure 2: regressions of acceleration vs. subimpulses/body mass, vs. relative zerocrossing, vs. maximal braking and accelerating forces / body mass. (* $p<0.001$, ^{t} $p<0.1$)

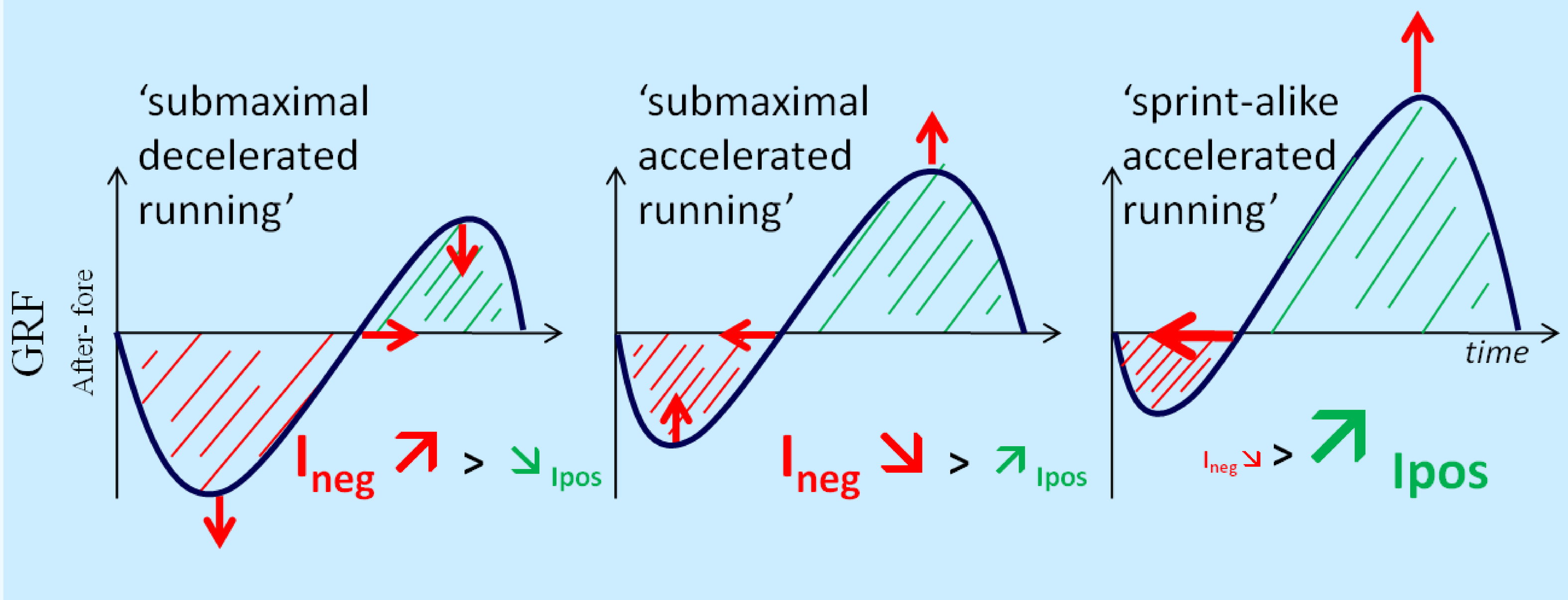

Figure 3: Strategies used to modulate braking and accelerating impulse.

CONCLUSIONS

Accelerated running with accelerations varying between 0 and 1.27m.s^{-2} are mainly realized by **decreasing braking impulse** due to a **decrease** in **braking force amplitude** and **relative braking duration.** Increased propulsion due to an increase in propulsive force amplitude and relative propulsive duration contributes in a lesser extent to a higher acceleration.

REFERENCES & ACKNOWLEDGEMENTS

[1] Hunter, et al., *J Appl Biomech* (2005), **21**: 31-43.
[2] Kugler, et al., *J Biomech* (2010), **43**: 343-348.
[3] Roberts, et al., *J Exp Biol* (2002), **205**: 1485-1494.
[4] Orendurff, et al., *Gait Posture* (2008), **27**: 603-610.

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