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Raphael Mesquita[a*], Mario Nuñez-Lisboa[a, b], Arno Marotta[a], Marine Moulin[a], Arthur Dewolf[a]

a Laboratory of biomechanics and Physiology of Locomotion, Institute of NeuroScience, Université catholique de Louvain, Louvain-la-Neuve, Belgium
b Exercise Science Laboratory, School of Kinesiology, Faculty of Medicine, Universidad Finis Terrae, Santiago, Chile
* Corresponding author: raphael.mesquita@uclouvain.be

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1. Introduction

Gait stability is crucial for functional independence in older adults, as it is closely associated with an increased risk of falls and mobility loss. While physical activities like running offer significant health benefits, they challenge gait stability (Savelberg et al. 2007).

To effectively assess stability, one should quantify variability between and within an individuals, as excessive fluctuations in stride parameters can indicate compromised control mechanisms. One approach to measuring variability is through signal entropy, capturing the complexity and adaptability of gait patterns. Higher entropy may indicate a healthier, more adaptable system, whereas lower entropy can reflect rigidity, chaos or loss of control.

By analysing gait entropy alongside traditional measures of inter-subject variability like the coefficient of variation (CV), we aim to improve understanding of gait stability differences between a young and older population during running.

2. Methods

Fifty-nine young and older adults (young & old age: 27±5 & 73±5 years, mean ± SD) participated in this study. Age groups were further split about evenly by physical activity level (less and more active), based on the median level of physical activity, measured *via* the Global Physical Activity Questionnaire. All participants provided informed consent, and procedures were approved by the local ethics committee.

Subjects ran on an instrumented treadmill at 9 and 12 km h^{-1} for 15-30 s, and ground reaction forces were recorded over 30 to 80 strides per trial.

Gait variability was computed with approximate entropy (ApEn) as in (Chon et al. 2009) on the vertical force signal (F_v) over all full strides and compared to spatiotemporal parameters. To measure inter-subject variability we computed the coefficient of variation ($\frac{SD}{mean}$). Effects of age and activity level were evaluated *via* a linear mixed model.

3. Results and Discussion

Step frequency (SF) increased within age ($F = 12.9$, $p < 0.001$) but training had no effect in either population ($p = 1$). While average SFs were similar within age groups, the CV in the older population was two times larger in the untrained group compared to the trained group.

ApEn increased with training at old age ($F = 5.8$, $p = 0.006$) but was not different between young trained and untrained populations ($p = 1$). Furthermore, despite the increased signal predictability in the untrained older population, the ApEn CV was twice as large compared to the trained older population.

Table 1. Coefficient of variation for SF and ApEn.

	Y^-	Y^+	O^-	O^+
CV - SF	0.014	0.015	0.036	0.018
CV - ApEn	0.045	0.045	0.139	0.049

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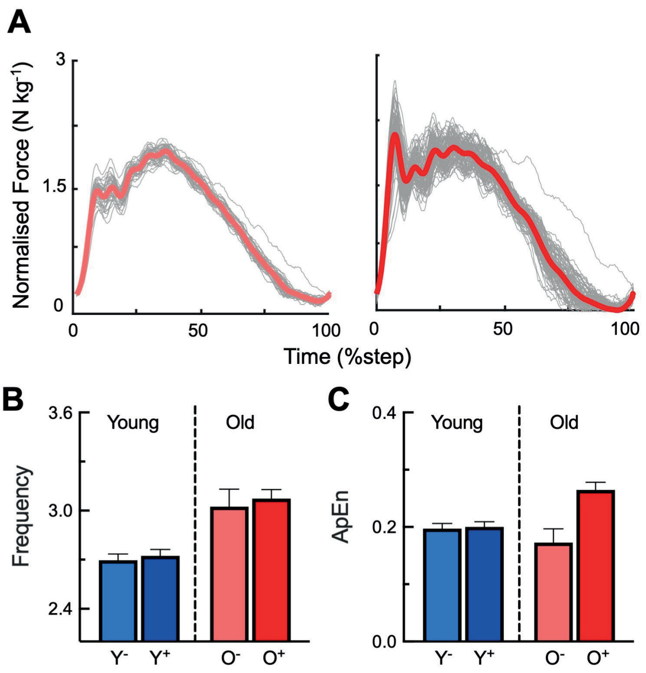

Figure 1. A) Typical trace of all steps, grey and average, thick line for two separate old less trained, left and trained, right subjects. Below: SF (B) and ApEn (C) in young and old populations at different physical activity levels.

Superscript: - indicates less trained and + more trained

In what may seem contradictory, as stability decreases under complex conditions— such as running on uneven vs even surfaces—the motor system becomes less complex yet more robust (Santuz et al. 2018).

Here, we show that when older adults run on a treadmill, a task demanding both muscular and stability control, they increase their step frequency to shorten step length and enhance stability. Furthermore, when comparing older trained and untrained adults, we show that the untrained group has higher inter-subject variability and lower entropy.

It has been shown in fast repetitive upper limb movements rely more on feedforward control and existing internal models, due to high processing time, (Correia et al. 2022). Thus, at high SFs, this reliance is more pronounced, reducing the adaptability of the movement to perturbations and generating less variable (more robust) movement patterns, similar to the observations of Santuz et al. (2018). Furthermore, the larger coefficient of variation in the untrained group shows a less apt internal strategy for adapting to such situations.

Trained older adults had higher entropy, indicating a more refined motor control system likely due to the larger muscular strength (Nuñez-Lisboa and Dewolf 2024), supporting adaption to challenging conditions.

This could also explain why no difference in variability was observed between trained and untrained younger individuals. While younger participants also show differences in maximal quadriceps force, the difference is far lesser between both groups (Nuñez-Lisboa and Dewolf 2024).

A large limitation was that more than half of the untrained older subjects were unable to match the required task and maintain it for the entire trial. In the future, decreasing the speed and increasing the sample size could perhaps improve results.

4. Conclusions

Untrained older individuals exhibited more robust force patterns but less refined internal models. Training improved motor control, increasing variability to enhance adaptability.

In walking a general observation was that older adults had similar neuromechanical strategies to younger participants (both in less and more active individuals), here, although trained older adults did not display the same step frequency or entropy values as younger individuals, their increased entropy suggests an alternative but effective motor strategy, reflecting improved adaptability rather than a return to youthful patterns. These results highlight the importance of physical activity in mitigating age-related declines in gait stability.

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Conflict of Interest Statement

None.

Contributor Roles

Conceptualisation: AD, MN, Methodology: RM, Writing original draft: RM, MN, AM, MM, AD; Funding acquisition: AD, Validation: AD, Writing-review & editing: RM, MN, AM, MM, AD.

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Data, software, code availability

Code can be provided upon reasonable request.

References

Chon, K. H., Scully, C. G., & Lu, S. (2009). Approximate entropy for all signals. *IEEE Eng Med Biol Mag, 28*(6), 18–23. https://doi.org/10.1109/MEMB.2009.934629

Correia, J. P., Vaz, J. R., Domingos, C., & Freitas S. R. (2022). From thinking fast to moving fast: motor control of fast limb movements in healthy individuals. *Reviews in the Neurosciences, 33*(8), 919–950. https://doi.org/10.1515/revneuro-2021-0171

Nuñez-Lisboa, M. N., & Dewolf, A. H. (2024). The role of physical activity in mitigating age-related changes in the neuromuscular control of gait, *npj Aging 11*, 49. https://doi.org/10.1038/s41514-025-00239-8

Santuz, A., Ekizos, A., Eckardt, N., Kibele, A., & Arampatzis, A. (2018). Challenging human locomotion: stability and modular organisation in unsteady conditions. *Sci Rep., 8*(1), 2740. https://doi.org/10.1038/s41598-018-21018-4

Savelberg, H. H. C. M., Verdijk, L. B., Willems, P. J. B., & Meijer, K. (2007). The robustness of age-related gait adaptations: Can running counterbalance the consequences of ageing? *Gait & Posture. 25*(2), 259–266. https://doi.org/10.1016/j.gaitpost.2006.04.006