Age-specific generalization in walking adaptation: the role of training speed

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Introduction

As life expectancy increases, understanding healthy aging has become increasingly important (1). Healthy aging affects walking by increasing variability and reducing automaticity (1). Conditions like stroke – which are more common in older adults – further impair walking and often lead to asymmetries (2). Treating walking impairments is critical, as they reduce quality of life by increasing fall risk and limiting independence (1,2). However, the effectiveness of current rehabilitation interventions remains limited (2).

A significant issue is that improvements gained during rehabilitation do not fully generalize to everyday walking outside of controlled clinical settings (2,3). Therefore, it is essential to identify the factors mediating generalization and how they vary with age. In this study, Mariscal et al. investigated how walking speed in a treadmill-based intervention influences generalization to natural overground walking in older versus younger adults (3). They hypothesized that older adults would generalize more after training at slower speeds – as these may be more natural to them (4) – whereas younger adults would generalize more after training at faster speeds.

Generalization in split-belt adaptation requires optimization

Split-belt treadmill adaptation is an emerging intervention where people walk on a treadmill with separate belts – one per leg – that move at different speeds (2,3). This intervention changes people's baseline asymmetries and holds promise for addressing persistent walking impairments post-stroke (2). Yet, generalization remains incomplete: when we train people to walk differently on the treadmill, they walk differently overground too, but less so than on the treadmill (3).

Evidence suggests that generalization may be improved by minimizing differences between training conditions and natural walking environments in two distinct ways: 1) by ensuring that the movements experienced during training remain within the natural range of everyday walking patterns (e.g., adapting people gradually to avoid large asymmetries) (5), and 2) by reducing sensory discrepancies between the training environment and everyday walking contexts (e.g., occluding visual cues) (6). However,

work in walking adaptation remains limited and focused predominantly on younger adults. Given aging's distinct impacts on walking and sensory processing, examining age-specific generalization factors is essential (1).

A protocol to examine age-specific factors for generalization of walking adaptation

To address this gap, Mariscal et al. examined age-specific effects of training speed on generalization (3). Since older adults generally prefer slower walking speeds compared to younger adults (4), Mariscal et al. predicted that generalization would be greater when training older adults at slower speeds, while the opposite would be true for younger adults.

Young (21±6 years) and older (73±5 years) participants completed a traditional treadmill-based walking adaptation protocol and were assigned to adapt at either Fast or Slow speeds. For Young Slow and Older Slow groups, the “mean” speed in adaptation was set to 0.8m/s. For Young Fast and Older Fast groups, the “mean” speed in adaptation was set to each participant’s “fast yet comfortable pace” determined with a pre-test (averaging 1.17m/s across young participants, 1.10m/s across older). After adaptation, all participants walked overground at their comfortable speed; generalization was evaluated as the increase in step length asymmetry at the start of this phase as compared to baseline.

Older adults generalize more with slower speed training, younger with faster

Mariscal et al. evaluated the combined effect of Age and Training Speed on treadmill-to-overground generalization (3). As predicted, generalization was larger in older adults who trained at Slow speeds compared to those who trained at Fast speeds. Also as predicted, young adults showed the opposite effect – generalization was larger in young adults who trained at Fast speeds compared to those who trained at Slow speeds.

These results align with some previous findings but contrast with others. Earlier studies reported mixed outcomes on whether older adults generalize more than or similarly to young adults after adapting at slow speeds (7,8). Unlike Mariscal et al., these studies used abrupt perturbation schedules, which are known to reduce generalization in young adults but whose impact on older adults remains untested – making a unified interpretation difficult. Mariscal et al.’s results also differ from studies suggesting that walking speed does not influence generalization (9,10). However, these studies manipulated overground rather than training speed and only tested young adults. Future work is needed to disentangle the complex interplay of factors influencing generalization and clarify observed discrepancies.

Generalization reflects training-overground speed consistency in older adults only

Mariscal et al. conducted additional analyses to explore potential mechanisms underlying the age-specific speed effect on generalization (3). Specifically, they asked whether greater generalization may stem from smaller discrepancies between training and overground walking speeds – consistent with the theory that more natural-like training conditions generalize better (1,5,9). For each participant, they measured discrepancy between "mean" adaptation speed and post-adaptation overground speed. Then, they examined whether groups with greater generalization were also those with smaller speed discrepancies. Indeed, Older Slow adults had smaller speed discrepancies than Older Fast adults, aligning with their greater generalization. Conversely, there was no significant difference in speed discrepancy between Young Fast and Young Slow adults.

Credit assignment theory posits that when we train on a treadmill, we generalize the changes deemed intrinsically helpful for future walking, and abandon those solely helpful on the specific treadmill (5,9). Accordingly, training under conditions that resemble one's natural walking – such as at similar speeds – may feel more intrinsically relevant and increase generalization. While findings in young adults appear contradictory, the analysis did not directly compare participants' training speeds to their natural walking speeds. Instead, it used post-adaptation overground speeds measured on a short 6-meter walkway that required frequent turning (3). The average overground speed in young adults was 0.9m/s – markedly slower than the normative value of 1.4m/s (4) – suggesting it may not reflect their true natural walking speed. Future studies should test whether naturally fast older adults generalize better at slow speeds, and vice versa for slow young adults.

Conclusions

Mariscal et al.'s findings demonstrate that generalization is modulated in age-specific ways. They showed that – opposite to young adults – older adults generalize more after training at slower speeds. This provides an essential step towards advancing motor rehabilitation, suggesting that training older adults at slower, more comfortable speeds may improve generalization and therapeutic effectiveness. More broadly, the study underscores the importance of tailoring interventions to age-specific needs, reinforcing the value of patient-centered interventions.

References

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