Age-Related Differences in Mental and Physical Fatigue Effects on Working Memory and Gait Balance

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Summary

Fatigue impacts cognitive and motor performance across age groups, yet its differential effects on working memory and gait stability remain poorly understood. This study examined how mental and physical fatigue differently affect working memory and gait characteristics in young and older adults. Results revealed distinct age-dependent effects of both fatigue types on cognitive and motor performance, suggesting the need for age-specific approaches to fatigue management.

Introduction

Fatigue is a pervasive phenomenon affecting up to 38% of the general population, impacting both cognitive and motor performance [1]. Despite being manifestations of the same phenomenon, mental and physical fatigue may affect cognitive and motor function differently across age groups [2,3]. This study aimed to examine how mental and physical fatigue differently affect working memory performance and gait balance control between young and older adults, exploring interactions between fatigue type, time, and age.

Methods

Ten young adults (5F, age: 22.3 ± 3.3 yrs) and 10 older adults (5F, age: 69.6 ± 6.0 yrs) completed two separate fatigue protocols (mental and physical) in a randomized order, with pre- and post-fatigue assessments in each session. The mental fatigue protocol consisted of a 50-minute individualized working memory dual-task paradigm. The physical fatigue protocol involved a sub-maximal treadmill test with incrementally increasing incline and speed until participants reached predetermined metabolic goals or became fatigued and could not proceed.

Assessments included subjective fatigue and energy levels (VAS-F), working memory performance, and gait parameters during preferred-speed walking. Dependent variables included cognitive performance accuracy, gait velocity, step length, stride width, and whole-body center of mass (CoM) mediolateral (M-L) movement parameters.

Statistical analysis employed a 2 × 2 × 2 (Fatigue Type × Time × Age) mixed-design repeated measures ANOVA to analyze the effects on all outcome measures. Significant effects were followed up with Bonferroni-corrected pairwise comparisons with $\alpha = .05$.

Results and Discussion

Both fatigue protocols significantly increased subjective fatigue and decreased energy levels across age groups ($p < .001$). Working memory performance unexpectedly improved post-fatigue in both groups, with older adults showing larger gains (mental: 42.0% to 52.0%; physical: 46.0% to 54.0%), though young adults performed better overall (mean difference = 18.5%, $p = .021$). Cognitive enhancement post-physical fatigue aligns with research on exercise-induced cognitive benefits[4], while improvements after mental fatigue suggest successful compensatory mechanisms, particularly in older adults' cognitive resource allocation.

Step width increased significantly only after physical fatigue in both young and older adults ($p \leq .005$), while M-L CoM peak velocity at heel strike increased following both fatigue types, with larger increases after physical fatigue. The greater impact of physical fatigue on gait dynamics likely reflects direct neuromuscular effects, while smaller changes following mental fatigue suggest preserved compensatory mechanisms in gait control under cognitive load.

Conclusions

Age-independent cognitive improvements and fatigue-specific gait adaptations challenge traditional assumptions about mental and physical fatigue effects.

References

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Table 1: Fatigue-Induced Changes in Cognitive and Motor Performance by Age Group

Variables	Fatigue Type	Young Group		Older Group	
		Pre	Post	Pre	Post
VAS-F Fatigue Level (out of 130 pts)	Mental	53.9 ± 18.8	79.4 ± 14.8	39.9 ± 29.6	55.1 ± 37.4
	Physical	52.4 ± 23.6	67.9 ± 25.1	41.5 ± 29.3	54.3 ± 34.3
VAS-F Energy Level (out of 50 pts)	Mental	27.7 ± 5.0	21.7 ± 8.4	31.8 ± 12.9	27.1 ± 11.5
	Physical	27.2 ± 11.7	20.7 ± 11.4	29.4 ± 12.7	12.9 ± 11.7
Working Memory Performance (digits span reverse in accuracy %)	Mental	61.0 ± 22.7	66.0 ± 26.6	42.0 ± 18.7	52.0 ± 20.4
	Physical	60.0 ± 17.8	64.0 ± 22.1	46.0 ± 22.2	54.0 ± 23.2
Gait Velocity (m/s)	Mental	1.362 ± .180	1.435 ± .183	1.315 ± .115	1.262 ± .230
	Physical	1.426 ± .220	1.447 ± .153	1.309 ± .117	1.295 ± .171
Step Length (cm)	Mental	73.8 ± 4.6	76.4 ± 5.3	69.8 ± 4.7	69.8 ± 7.3
	Physical	75.7 ± 5.8	76.2 ± 4.2	70.2 ± 7.3	70.5 ± 7.7
Step Width (cm)	Mental	18.5 ± 2.4	18.4 ± .2.4	14.3 ± 4.4	14.8 ± 3.4
	Physical	18.1 ± 3.0	20.8 ± 2.7	13.4 ± 4.4	15.7 ± 4.1
M-L CoM Peak Velocity at Heel Strike (cm/s)	Mental	-11.3 ± 2.8	-12.3 ± 2.8	-12.0 ± 4.2	-13.3 ± 4.3
	Physical	-11.6 ± 2.9	-13.2 ± 4.2	-11.9 ± 4.3	-15.6 ± 3.6
M-L CoM Peak Velocity at Toe Off (cm/s)	Mental	14.2 ± 3.2	15.6 ± 3.6	17.4 ± 4.6	15.8 ± 4.0
	Physical	16.4 ± 7.0	15.6 ± 3.0	15.2 ± 5.2	14.9 ± 6.5