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Exoskeleton vs End-Effector Robotic Gait Training in Subacute Stroke: Stage-Specific Recovery and Efficiency

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Objective

Robot-assisted gait training (RAGT) is widely used in subacute stroke rehabilitation; however, comparative evidence between exoskeleton- and end-effector-based systems across recovery stages remains limited. This study compared longitudinal functional and cardiopulmonary effects of Lokomat (exoskeleton) and Morning Walk (end-effector) systems and evaluated stage-specific differences.

Method

This retrospective cohort study included 154 patients with subacute stroke (≤6 months post-onset) who completed ≥20 RAGT sessions (Lokomat n=91; Morning Walk n=63). Functional outcomes included Fugl–Meyer Assessment–Lower Extremity (FMA-L), Functional Ambulation Category (FAC), Berg Balance Scale (BBS), and Mini-Mental State Examination (MMSE). Cardiopulmonary outcomes included oxygen consumption (VO_2), carbon dioxide production (VCO_2), oxygen rate (mL/kg/min), and energy cost of walking. Linear mixed-effects models were used to analyze longitudinal changes.

Results

Both modalities produced significant improvements in motor function, ambulation, balance, and cognition, exceeding established minimal clinically important differences. In the overall cohort, balance improvement was significantly greater in the Morning Walk group (between-group difference 3.4 points, P=0.04) (Fig 1). Significant reductions in VO_2 and VCO_2 were observed only in the Morning Walk group, with significant between-group differences favoring this modality (VO_2 P=0.007; VCO_2 P=0.011). Energy cost of walking decreased significantly only in the Morning Walk group (Fig 2). Stage-specific analyses revealed differential effects. In the early subacute phase, Lokomat training was associated with greater improvements in FMA-L (P=0.03) and MMSE (P=0.01) (Fig 3). In contrast, during the late subacute phase, Morning Walk training resulted in significantly greater improvements in FMA-L (P=0.049) and BBS (P<0.001) (Fig 4).

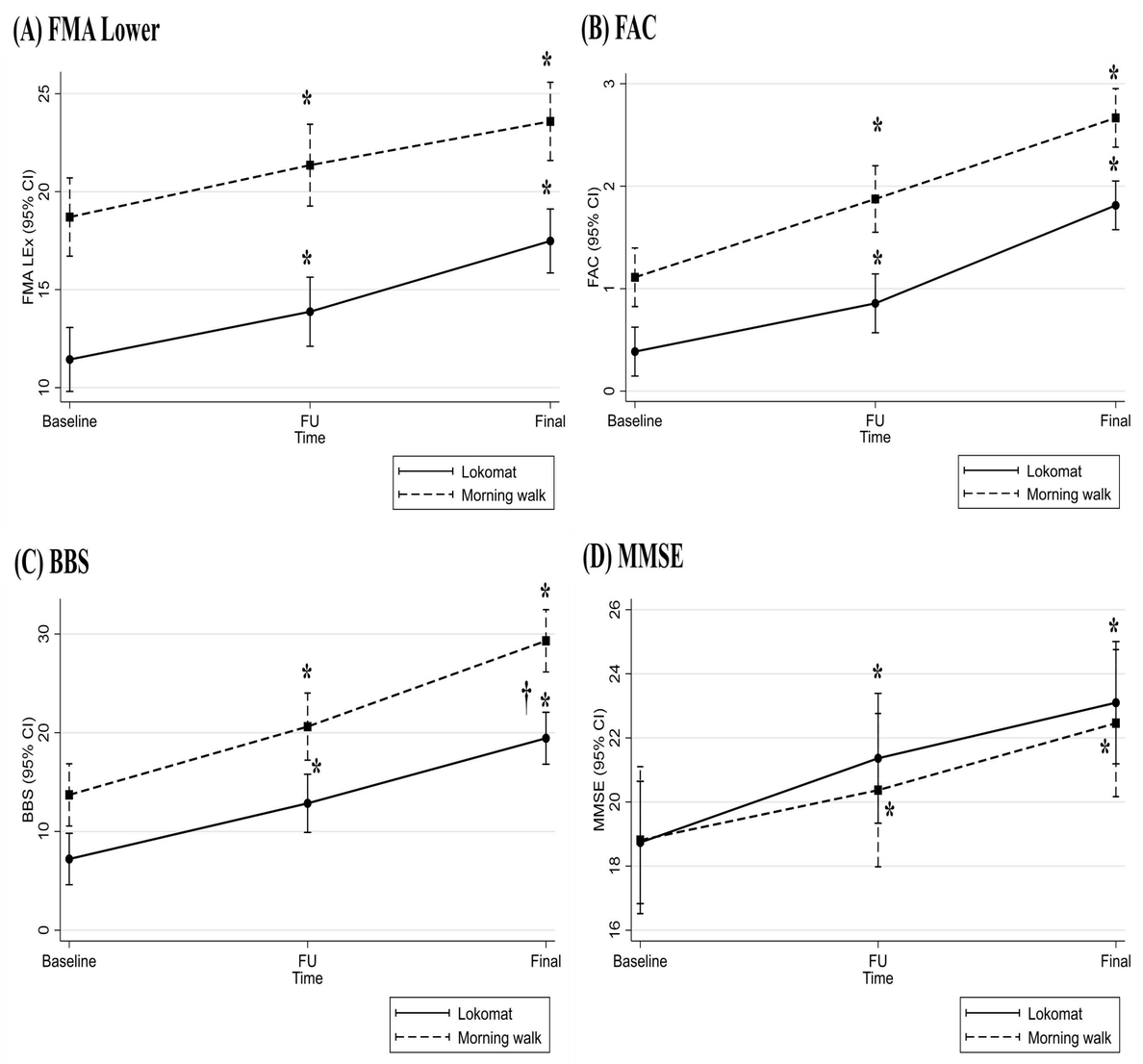

Figure 1. Changes in functional outcomes in the overall cohort

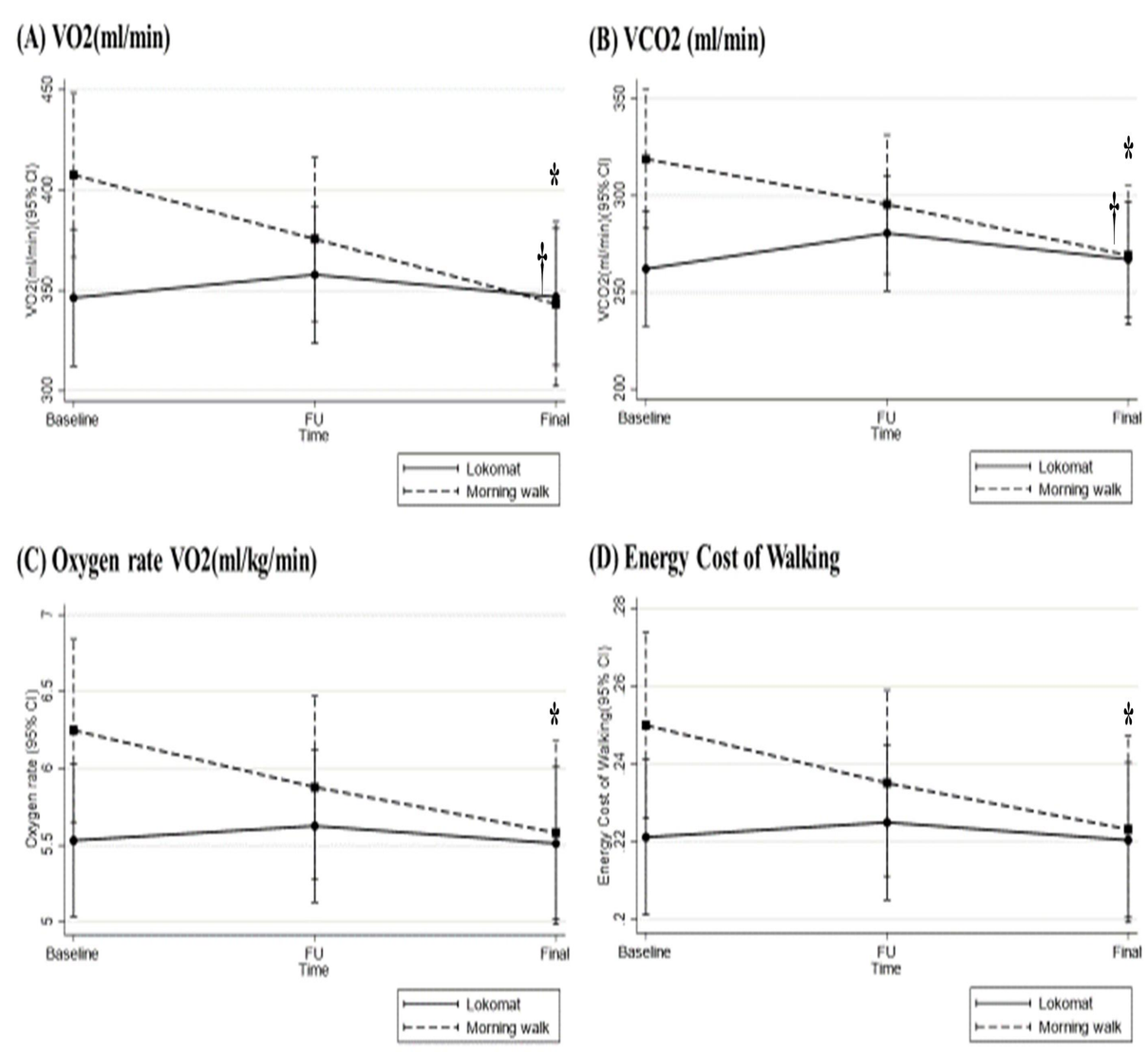

Figure 2. Changes in cardiopulmonary and energy efficiency outcomes

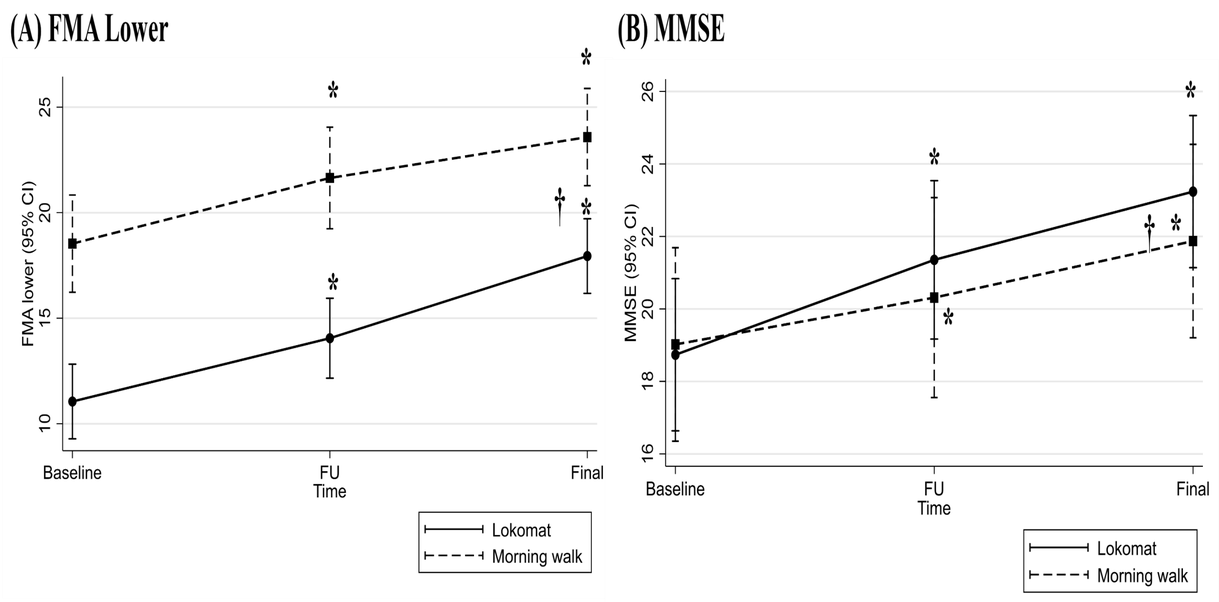

Figure 3. Effects of robotic gait training in the early subacute phase after stroke

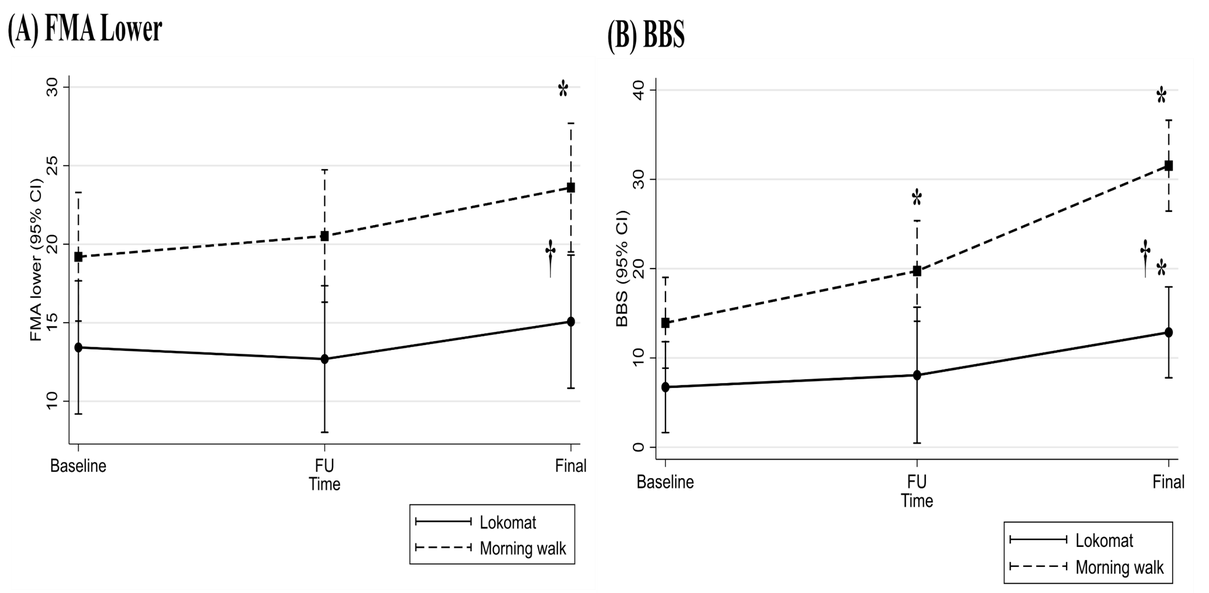

Figure 4. Effects of robotic gait training in the late subacute phase after stroke

Asterisks (*) denote significant within-group changes from baseline (P < 0.05)
Daggers (†) denote significant between-group differences in the magnitude of change (P < 0.05)

Conclusion

Both exoskeleton- and end-effector-based RAGT facilitate meaningful functional recovery in subacute stroke. However, physiological adaptations and stage-specific functional responses differ according to device type. Exoskeleton-based training may be advantageous in early subacute stroke for guided motor recovery, whereas end-effector-based training may better enhance balance and walking efficiency in later stages. These findings support a stage-specific, goal-oriented approach to robotic gait rehabilitation.