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Salvatore Tedesco: Integrating Wearable Technology and Machine Learning for Early Detection and Intervention in Age-Related Mobility Decline

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Introduction: Aging is associated with declines in neuromuscular control, mobility, and overall physical function, increasing the risk of frailty and reduced quality of life. Early detection and targeted interventions are critical in mitigating these effects. At Tyndall National Institute, we have explored evidence-based approaches to assessing and improving physical activity (PA) in older adults, leveraging wearables, machine learning (ML), and neuromuscular control analysis to optimize clinical interventions.

Methods / Results: Three key research approaches investigated on the topic:

1. Mobility Assessment: A cohort of older orthopedic patients (n=113, median age 78) wore ankle accelerometers to assess gait patterns before and after a Frailty Care Bundle intervention targeting mobilization, nutrition, and cognition. A Random Forest classifier (74.7% accuracy) and logistic regression model (77.6% accuracy) were used to analyze gait parameters such as stride length, gait speed, and Lyapunov exponent to assess intervention impact.

2. Frailty Detection: A separate study utilized wrist-worn consumer activity monitors to predict hand grip strength—a key indicator of frailty—using 7-day accelerometry data and ML models. Classification models achieved AUC-ROC scores of 0.86–0.87, demonstrating the feasibility of frailty/pre-frailty screening in free-living environments.

3. Neuromuscular Control Analysis: To evaluate age-related neuromuscular decline, dynamic motor control index (DMCI) was assessed during walking and stepping tasks in older vs. younger adults. One-synergy variance accounted for (VAF) metrics revealed significant age-related differences during stepping forward exercises ($p = 0.033$), indicating potential for early detection of neuromuscular deficits.

Discussion: The Frailty Care Bundle intervention improved gait speed and altered stride characteristics, though long-term adaptive benefits remain unclear. ML models demonstrated moderate-to-high accuracy in predicting frailty and grip strength, supporting the potential for consumer-grade wearables as practical clinical assessment tools in older adults. Neuromuscular control analysis using DMCI and one-synergy VAF metrics effectively identified age-related neuromuscular decline, possibly serving as low-cost accessible methods for detecting early motor control deficits.

Conclusion: Integrating wearables, ML, and neuromuscular control assessments presents a promising, data-driven approach to monitoring and improving PA in older adults. These findings highlight the potential of personalized, evidence-based interventions to enhance frailty detection, rehabilitation, and mobility outcomes in aging populations.

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