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Digital Technology Bundles:

A Testing and Validation Blueprint for Fall Prevention

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Background

Falls are the leading cause of injury, both fatal and nonfatal, for adults aged 65 and above.[1] One in four older adults reports falling each year, leading to three million emergency department visits, over one million annual hospitalizations, and medical expenditures that are projected to reach $100 billion by 2030.[2] Injury-related hospitalizations from a fall in older adults often trigger a cascade of poor health outcomes and adverse events, including a one-year mortality rate as high as 30 percent if a hip fracture occurs.[3] In response, an array of fall-prevention technologies has become available, from AI-enabled gait monitoring sensors to fall-detection wearables—supplementing traditional screening and assessment approaches recommended for clinical practice.[4]

Despite advances in age-tech innovation, adoption remains low.[5] The proliferation of available tools in the care ecosystem is overwhelming to older adults and family caregivers who are left to stitch together suites of devices and digital health tools to meet their individual care and safety needs. They often rely on providers and health-care navigators for guidance in selecting appropriate interventions, even as many providers are overburdened and struggling to keep abreast of rapid technology advancements.

An abundance of “point solutions”—apps, products, services, and devices that address only a single issue or perform a standalone function—leads to a fragmented, piecemeal approach to prescribing, recommending, and employing these technologies. Users want bundling and consolidation: fewer tools that do more and are not redundant.[6] However, there is limited research on multifactorial, bundled digital health interventions that integrate fall prevention, early detection, and outcome monitoring.[7]

Our premise is that the benefits of integrating digital technologies into home settings and care facilities are greatest when they are bundled and deployed together. This proposition builds upon our May 2025 report, *The Future of Connected Care: Enabling Healthy Longevity and Aging at Home*, in which we recommended establishing a taxonomy of tech-enabled solutions based on function and purpose and building an evidence base to guide implementation.[8] Here, we apply these recommendations to the practical test case of fall prevention.

The blueprint presented below offers a taxonomy for classifying fall-prevention technologies and trial frameworks for evaluating them. It provides a broad group of stakeholders with a starting point for bundling technology solutions that are easier to purchase, more efficient to implement, improve overall user experience and adoption, and are hopefully more effective in treating and preventing falls. While testing and data collection are most feasible in senior housing and/or care facilities, broader deployment in independent living settings holds promise for supporting aging at home.

Proposed Taxonomy for Fall-Prevention Technologies

The array of existing digital technologies for fall prevention can be classified according to their primary purpose. We propose grouping them into one of four categories organized through an approach we call Assessment, Prevention, Intervention, and Response (APIR) Classification.

Assessment consists of technologies that evaluate level of fall risk. Traditional fall-risk assessments and interventions have relied on provider–patient interactions. However, digital technologies can identify the need for further action without direct provider input and allow for targeted deployment of resources. Examples include an analysis of electronic health records using advances in software, predictive AI tools, and data integration to flag patients who will need prevention or intervention steps.[9]

These kinds of assessments can spur patients and providers to have conversations and allow for earlier deployment of preventive services that can avert future falls. Technology also presents opportunities to improve the precision of provider-based assessment (e.g., using a more sophisticated and easier-to-deploy gait analysis).[10]

Prevention consists of technologies that help individuals lower their general fall risk. Their purpose is to assist individuals who may categorically be a fall risk but do not display individual high-risk characteristics. Traditional occupational therapy or other methods of implementing preventive measures are resource intensive. However, technology solutions exist that offer in-home, online exercise regimens to help older adults with balance and strength training.

The development of virtual or app-based regimens can extend these programs, allowing for greater access and developing programs tailored to individual needs.[11] Smart home solutions can also lower fall risk by enhancing the physical environment, such as voice-controlled or motion-activated lighting.

Intervention includes technologies that signal the imminent threat of a fall in high-risk individuals. This type of technology can assist people and their caregivers with understanding fall risk on a particular day or under certain conditions, allowing for the targeted deployment of intensive resources where and when they are most needed. This includes integration of sensors, trackers, and continuous monitoring using gait analysis to alert caregivers of imminent falls, and smart socks that can notify care teams when an individual is attempting to stand or walk unassisted.[12]

Response technologies work post-fall and are designed to mitigate adverse outcomes in the immediate aftermath of a fall. Technologies such as wearables with accelerometers and non-wearable ambient systems, in which sensors are installed in an individual's environment, can detect falls and immediately alert caregivers and emergency services. This category of devices also includes technologies to assist in recovery from fall-related morbidity.

The APIR classification system is based on the premise that all four technology types can help prevent poor outcomes. **However, adequately addressing the complex contributors to fall-related injury and morbidity in older adults requires utilizing a technology in each of the four APIR categories.** Assessment, for example, is needed to identify candidates for prevention and intervention, but unless the latter two categories of technologies are deployed, that identification can only go so far. We believe that bundling purchases of digital technologies to address all four areas gives users the best opportunity to realize their full benefits, and fall prevention using APIR should not be considered a linear process, but rather a continuous and adaptive one.

Testing and Validation

Fall-prevention technologies are often tested, considered, and purchased individually.[13] Evidence of any benefits considers and evaluates the effect of each technology separately, rather than assessing a combined impact. We propose that developers, researchers, philanthropic organizations, and the investment community come together to conduct a trial of the simultaneous deployment of multiple technologies, most critically, a combination that includes at least one technology from each category of the APIR framework.

This blueprint outlines a trial that examines how technologies can work together. Our recommendation is to bundle different types of technology solutions into a single package to alleviate decision-making burdens, optimize user benefits, and improve health outcomes. Therefore, the testing goal is to adequately capture how bundles of fall technologies work jointly within the APIR classification framework.

Our proposed strategies rely on the ability to recruit large numbers of potential beneficiaries—individuals who have the condition that the intervention in question is designed to address. While the long-term goal is to establish bundles that will support older adults in their homes, the practicalities of implementation and collecting the necessary data mean that the first steps toward testing bundles are best taken in the context of congregate housing or senior living facilities. Further, senior housing operators are increasingly seeking opportunities to support older adults and participate in prevention efforts, with some long-term care residences already piloting new technologies directly with developers (e.g., smartphone-enabled gait analysis to track residents' mobility).[14] Age-tech accelerator programs also facilitate test beds that connect technology innovators with senior living communities.[15] The intent is to identify what combination of technologies works best together for future implementation in a broader array of home settings.

Currently, someone might use one type of technology while forgoing a second, as providers might recommend one remedy based on evidence of singular success. This approach overlooks the potential synergistic effects of these technologies when combined effectively. In an ideal system, different technology bundles would exist for differing needs, providing a discrete set of choices proven to work best together, rather than a one-size-fits-all approach. This is why we propose developing bundles following trials that consider multiple technologies at once.

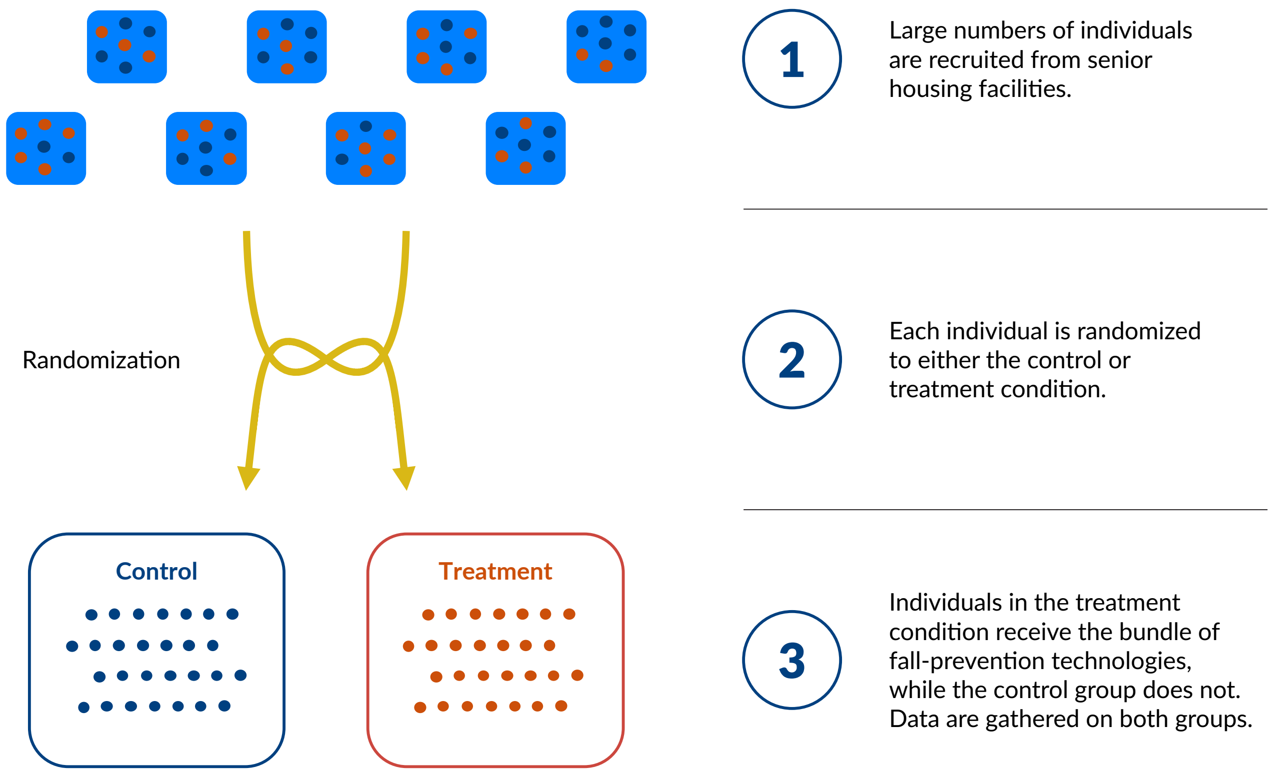
Traditional Randomized Clinical Trials

The first clinical-trial approach to consider is a traditional randomized control trial (RCT), in which a bundle of fall-prevention technologies is tested against control conditions (Figure 1). RCTs are the gold standard of evidence-based research practices. They are ideal for testing sole interventions under pristine conditions and underlie much of the evidence base regarding efficacy. Most fall-prevention technologies have been individually tested in this manner to establish their efficacy; however, our recommendation goes further.

To conduct this type of trial, one must have a priori established the treatment (e.g., the bundle of technologies to be tested). Such testing will rely on the willingness of various digital technology manufacturers to participate in research and provide their products for combined evaluation.

Problems with traditional RCTs are twofold: (1) they do not reflect real-world conditions under which actual treatments are provided and (2) they can only determine the singular effect of treatment versus control, not the individual and interaction effects of each technology. Ultimately, traditional RCTs focus on the efficacy of a singular treatment or intervention evaluated solo under pristine conditions, which is of limited utility in the proposed context.

Figure 1: Traditional Randomized Control Trials



Source: Milken Institute (2026)

Beyond the Traditional Randomized Control Trial

In addition to a traditional RCT, we propose alternative trial designs. While like the first RCT proposal in much of its execution, our second option uses a different method of randomization. Our third option uses a factorial design, so participants are assigned to one of 16 different conditions, instead of just to the treatment or control group.

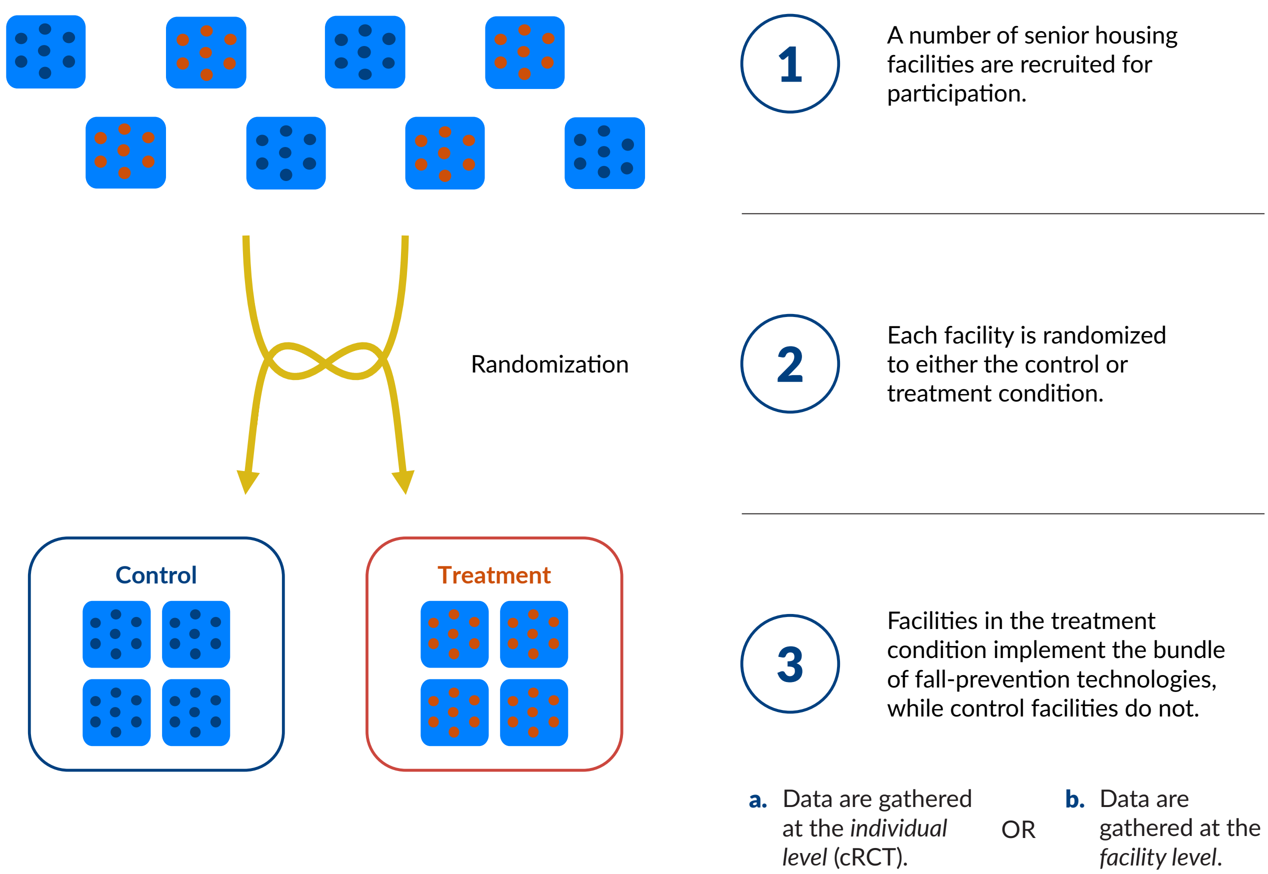
Randomization Across Facilities: Testing in the Context of Senior Housing

Pragmatic trials aim to remedy the first problem by broadening the external validity of research.[16] Such designs can inform researchers about problems that may arise, such as resource constraints or difficulties applying multiple technologies. Our first proposed alternative is facility-level randomization rather than individual-level randomization.

Randomization across facilities reflects a more pragmatic strategy, recognizing that administering a bundle to only some patients within a facility is challenging, particularly when multiple bundles may need to be tested simultaneously. Facilities should be able to test the same combination of interventions across all residents rather than provide different technologies to different patients according to their trial assignment. If the information collected is at the patient level, this would be considered a cluster randomized controlled trial (cRCT), a type of multilevel trial.

However, data can be gathered at either the patient level, in a cRCT, or at the facility level. Most trials are individual- or patient-level, assessing the effect of treatment on each patient's condition. However, RCTs for nonmedical interventions are often conducted across groups. For example, educational interventions are often tested at the classroom or school level. An RCT is also possible using facilities as the unit of analysis in facility-level RCTs (Figure 2).

Figure 2: Clinical Trials Randomized at the Facility Level



Source: Milken Institute (2026)

Regardless of whether the data are collected at the patient or facility level, randomization should happen at the facility level. While the treatment administration is the same in both cases, the data required, as well as the statistical analysis used to parse that information, are different.[17] Whether or not someone falls is an individual-level data point, but aggregate measures like total falls or total near-misses are facility measures. Fall-related expenditures are also relevant; however, focusing only on the monetary savings fails to recognize “soft” benefits such as increased feelings of security, enhanced psychosocial well-being, and improved older adult and caregiver satisfaction.

Objective measures, such as the number of falls, number of hospitalizations or injuries, and expenditures, are only one way of measuring the success of fall-prevention technology. Subjective measures that evaluate patient or caregiver perceptions of balance or safety are ways to try to capture these softer benefits. Lastly, it is important to capture some measure of each of the APIR phases. For example, a fall occurrence cannot adequately illuminate the success or failure of response technology. If the plan is to simultaneously test all four stages, then other outcomes should be considered for effective evaluation.

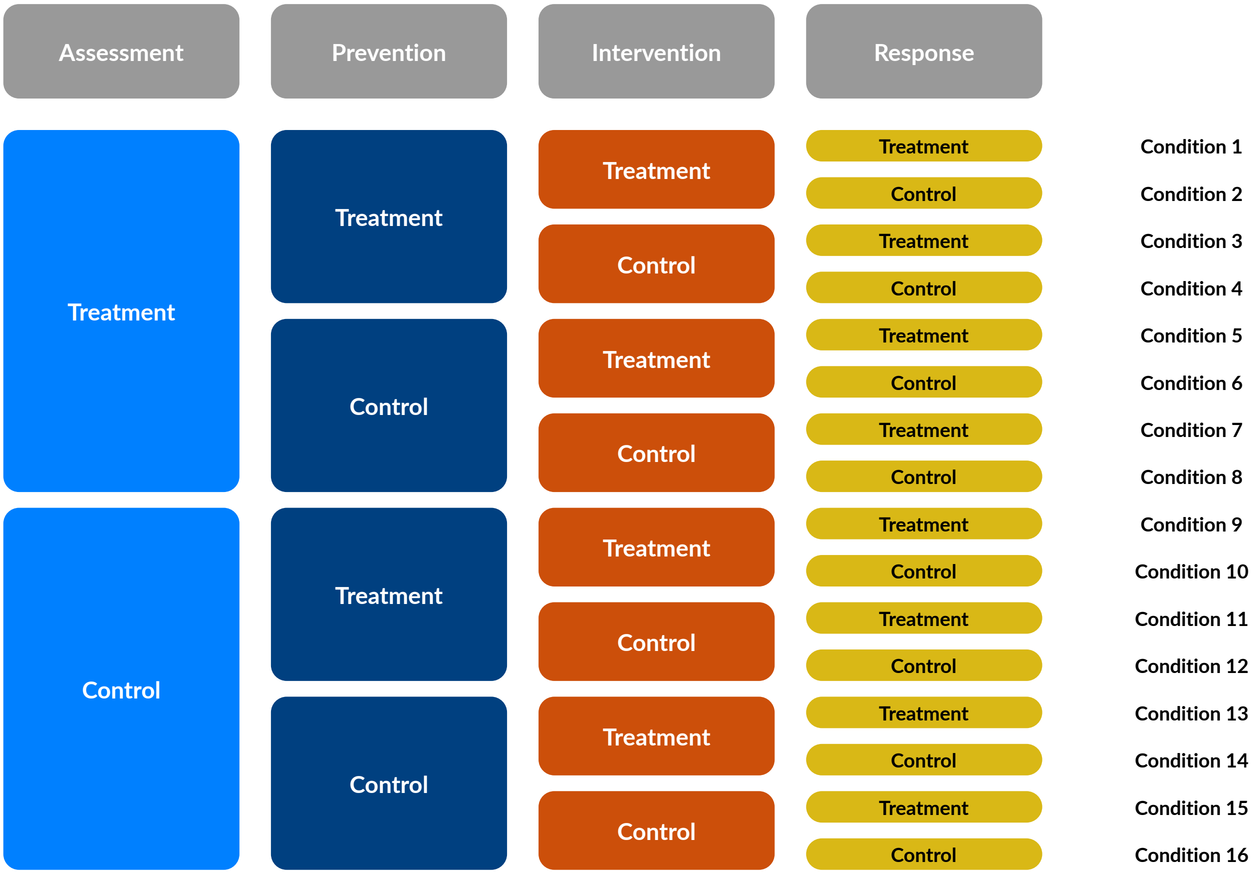
Factorial Design: Searching for Interactions Between Different Technologies

Neither a cRCT nor a facility-level RCT allows for testing the individual effects of each technology or for their interactions. Our next proposed alternative attempts to solve that inability of simple RCTs using a factorial design (Figure 3).

The specifics of such a design are best elucidated elsewhere;[18] however, in its most basic form, a 2x2 factorial design allows researchers to test two interventions, each with two conditions—most often, treatment versus control. In this design, participants are randomly assigned to one of four conditions. A participant receives either both treatments A and B, treatment A but the control for B, or the control for A and treatment B, or is part of the control group for both interventions and receives neither treatment.

One of the advantages of factorial design is its efficiency, as testing the main effects of treatment A can include participants in both conditions of treatment B and vice versa, allowing researchers to essentially “double dip” their participant pool. Most importantly, with enough power, researchers can estimate the interaction effects that the treatments exhibit when administered together. With enough participants, factorial design can expand even further, theoretically allowing the testing of a 2x2x2x2 or 2^4 design that could test all four stages of the model at once, requiring randomization across 16 treatment protocols.[19]

Figure 3: Randomized Clinical Trial with a 2^4 Factorial Design



Source: Milken Institute (2025)

Conclusion

This brief provides a roadmap for interested stakeholders in senior housing and care, technology, health care, and the investment community to classify and build the evidence for bundled fall-prevention technologies. There are numerous methodologies one might apply to an RCT framework for validating fall-prevention technologies *in combination*. We have proposed three different options to test in congregate housing or senior living facilities, and additional methodologies are possible.

The need for action is urgent because the number of older adults requiring this technology increases each year. Senior housing facilities, technology manufacturers, and care providers should identify a trial framework that works for their context and setting. By systematically testing these technologies, ideally through a rigorous but pragmatic trial, it will be possible to find the right combination of fall-prevention technology solutions that can be effectively deployed in any home setting.

Endnotes

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19. Sequential designs are worth consideration, either in tandem with or instead of the above designs (e.g., a stepped-wedge trial, a crossover trial, multiphase optimization strategy [MOST], and sequential multiple assignment trials [SMART]). Discussion of their application is beyond the scope of this brief.

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