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Learning From Falling: Retention of Fall Resisting Behavior Derived From One Episode of Laboratory-Induced-Slip Training

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To the Editor

Perturbation-related falls (trips or slips) account for >60% of outdoor falls among community-living adults aged 70 or older, and even the healthier older adults are not immune to devastating falls¹. It is therefore critical to develop intervention paradigms that can prevent such falls in elderly.

Preliminary evidence has shown that crucial adaptive skills for resisting falls can be acquired rapidly through a single-session of repeated exposure to slips (perturbation training) induced during sit-to-stand and gait among both young and older adults². This adaptation to slips was characterized by improving one's center of mass (COM) stability by an anterior shift of the COM and the increase of its velocity relative to the base of support (BOS)³. The purpose of this study was to determine whether such acquired fall-resisting motor skills could be retained for at least 6 months among older adults, a population known for general memory decay and age-related sensorimotor deteriorations.

Twenty-five community-dwelling, older adults (73.42±5.42 years, 1.69±0.10m tall and 74.59±12.57kg in weight; 13 female) participated, after being screened for neurological, musculoskeletal, cardiopulmonary conditions, mental state and osteoporosis (for safety reasons). The participants' walking speed was 1.03±0.22 m/s and 40% (10/25) of them had one fall in the past year. The study used an intent-to-treat approach and a prospective pre-post paired design to detect retention of the perturbation-training effect. A single session of laboratory-based perturbation training consisting of two initial, sequential blocks of repeated slip-nonslips (8 slips and 3 nonslip X 2) and subsequent mixed block of interspersed slips-nonslips (8 slips and 10 nonslips) was applied to all subjects (a total 24 slips and 16 nonslips). The subjects were to *implicitly* adapt to prevent falls or backward loss of balance (BLOB) upon perturbation exposure. Subjects were only told that upon a slip they should try to recover their balance and continue walking. The session lasted for approximately 60 minutes. Unpredictable slips were induced using computer-controlled release of low-friction platforms. Subjects were retested with an unpredictable single slip 6 months (6 mo) after this single-session training. Changes were obtained in incidence of laboratory falls (>30% body

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weight supported by the safety harness), BLOB (subjects landed the compensatory step behind slipping limb) and the dynamic stability (based on the COM position and velocity at trailing limb liftoff) (Figures 1a and b). These changes were examined between the first (S1) and last slips (S24) of the training session and the 6 mo retest slip, respectively, using the Friedman's test (with post hoc, χ^2 tests) and one-way repeated measures ANOVA (with post hoc paired t-tests). Adjustments for multiple post hoc comparisons were made. Subjects' real-life fall incidence over the 6 months after the training session was tracked via phone calls once every 6 weeks. Details of the experimental design, data collection and protocol can be found elsewhere^{2, 3}.

Older adults rapidly lowered fall and BLOB incidence with perturbation training and maintained it for 6 months ($[\chi^2(2,25)=20, p<0.001]$ for fall and $[\chi^2(2,25)=22, p<0.001]$ for BLOB). Within the first 5 slips, fall incidence reduced from 44% on S1 to <5% on the fifth slip trial (S5) and reached 0% by S24 ($p<0.01$ S1 vs. S24). Correspondingly, they reduced BLOB incidence from 100% on S1 to <15% by S5 and to 0% by S24 ($p<0.001$, S1 vs. S24). Subjects were able to retain the acquired fall-resisting skills with a reduction from 44% to 0% in falls, and from 100% to 52% in BLOB, between S1 to 6 mo ($p<0.01$, for both, Figure 1c). Only 4% (1/25) subjects reported a real-life fall over the 6 months.

There was a parallel adaptation and retention in stability over 6 months [$F(2,74)=107.44, p<0.001$]. There was significant improvement in COM stability from S1 to S24 ($p<0.001$), which was maintained for a longer-term period ($p<0.01$ from S1 to 6 mo, Figure 1d). Nonetheless, there was still a measurable motor memory decay characterized by a significant increase in incidence of BLOB and decrease in stability from S24 to 6 mo ($p<0.05$).

The findings of retention in old were similar to young adults³, and they lend support to the potential usefulness of the perturbation training paradigm for fall prevention. Significant improvements in stability have led to decreased risk of falls and BLOB in young adults⁴, as well as among older adults for a long period of 6 months in the present study. There is also evidence that older adults can retain newly acquired fine motor skills for years without intervening rehearsals⁵. Attempts were also made to examine longer-term effects of laboratory-based perturbation training in older adults^{6, 7}. Low kinematic intensity in those cases might not be challenging enough to induce true experience of falls. Hence, the postulated training effects for fall-prevention are yet to be verified^{6, 7}. Further, the optimal level of perturbation to induce sustainable fall resistance is also needs to be determined.

It is possible that the demonstrated improvement in stability and slip outcome (fall and BLOB) could be specific to the training environment with limited translation to real-life. Our recent findings have demonstrated that the effects of platform perturbation training could generalize to real-life floor slips in young adults⁸. Further, the lower incidence of real-life falls post- (4%) versus pre-training (40%) in this subject group lends some support for translation of this paradigm from laboratory to real-life settings. Note that the past fall incidence recorded in the study sample is consistent with the reported rate of falls in the older adult population¹. Clearly, one of the next steps is to systematically determine and quantify carryover of the laboratory training to everyday living⁹.

This is the first piece of evidence on the preservation of the fall-resisting motor memory among older adults which could be analogical to "learning from falling" observed in early childhood¹⁰. One of the differences between the childhood learning and learning among older adults is that the latter group may be able to draw upon motor memory components built from previous error-driven learning experience to modify their behavior. In contrast, the former group possesses only a limited repertoire and would be still building such

experience-related motor memory. This may partially explain the rapidness of the adaptive change in outcomes induced via the perturbation training in this study, compared to hundreds of falls a child may experience before they are able to establish their full and stable postural control.

In summary, perturbation training that mimics real-life conditions could have far-reaching clinical implications by facilitating learning of fall-resisting skills in a well-protected environment (similar to training wheels on a bicycle) ¹⁰. Based on such emerging evidence, it may be possible in the future to ‘inoculate’ older adults to reduce their likelihood of falls.

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a) Example of falls & BLOB

b) Retention in stability

Figure 1.

Photo snap shot representation of slip outcome classification: (a-1) an older subject who fell and (a-2) one who experienced backward loss of balance (BLOB), on the first novel slip, induced after stepping on the low-friction platform that was released unexpectedly during walking, shortly after right touchdown. Image a-1 corresponds to the instance of fall termination and a-2 to postslip touchdown of contralateral, trailing limb. b) COM state stability (means+SD, gray filled symbols) demonstrated on the first and last slips of the initial training session (S1 and S24 respectively) and the 6-month retest slip (6-mo). Also shown are values from individual participants (open symbols) for each of the 3 trials S1 (circle), S24 (square) and 6-mo (diamond) connected by solid lines. * indicates a significant level of $p < 0.05$ and ** a level of $p < 0.01$ between group means.