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A Strategy Utilizing Simple Clinical and Laboratory Tests to Identify Fallers among Healthy Independently-living Older Persons

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A STRATEGY UTILIZING SIMPLE CLINICAL AND LABORATORY TESTS TO IDENTIFY FALLERS AMONG HEALTHY INDEPENDENTLY-LIVING OLDER PERSONS

By

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Background and Purpose: Falls are the leading cause of accidental death among older adults. Reducing falls risk is one of the major safety concerns for older persons. More than one-third of people 65 years and older will experience one or more falls per year and nearly half of the people over 80 years of age will fall at least once each year. A key initial step in reducing falls is identifying those persons at highest risk so that they can be assessed and prescribed appropriate interventions. Therefore, the purpose of this study was to examine the capacity of a number of field and laboratory tests to identify fallers in a sample of older independently-living, community-dwelling persons.

Participants: 66 healthy, independently living older persons, ages 60 and older.

Method: During three visits to the laboratory, participants performed various field and laboratory balance tests. Field tests included the Timed Up and Go Test (TUG), the One-Leg Stand Test (OLS), the Functional Reach Test (FR), and the Tinetti Performance Oriented Mobility Assessment (POMA). The laboratory tests included a center of pressure (COP) test with time-to-boundary (TTB) measurements on a force platform, and dynamic posturography using the Proprio 5000. Each participant was classified as a "faller" or "non-faller" based on whether he or she recalled experiencing a fall within the past year.

Results: Receiver-operated characteristics (ROC) curve analyses (specificity and sensitivity throughout the measurement ranges) revealed the OLS and TUG field tests and selected Proprio 5000 and TTB variables had the best capacity to distinguish fallers from non-fallers. For both field and laboratory tests one-way ANOVA revealed between-group differences similar to those indicated by the ROC results.

Discussion and Conclusion*:* Both selected field and laboratory tests could identify fallers (16 out of 66). In addition, the laboratory tests revealed balance decrements in specific planes of motion that provide information concerning directional falls risk and a offer a framework for the prescription of interventions to reduce that risk.

Key Words: Older persons, falls assessment, fall prevention, balance, Proprio 5000

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CHAPTER 1: INTRODUCTION

Falls are the leading cause of injury death among older adults.[1] In fact, more than one-third of people 65 years and older will experience one or more falls per year[2] and nearly half of the people over 80 years of age will fall at least once each year.[3] In the United States, approximately 16,000 persons over 65 died as a result of injuries from falls in 2005, about 1.8 million were treated in emergency departments for nonfatal injuries from falls, and more than 433,000 of these patients were hospitalized. Furthermore, it has been estimated that by 2040 the number of hip fractures will exceed 500,000.[4]

People who fracture a hip due to a fall usually spend an average of one week in the hospital[5] and 25% of independently living older persons who fall with injury require a stay of at least one year in a nursing home.[6] Finally, one of every five older persons who fractures a hip dies within one year of the injury.[7]

Falls also have significant financial impact. In 2000, the total direct cost of all fall injuries for people 65 and older exceeded $19 billion[8] and this is expected to increase to $43 billion by 2020 as our population becomes more "gray".[9]

Given the frequency of falls and the dire consequences associated with falling, reducing the probability of falling is an important strategy. Therefore, the early detection of persons with a predisposition to falling is vital, since this allows time for referral to a fall intervention program.[10] Questionnaires that assess risk factors, history of falls, and fear of falling are among the tools used for identifying fallers; [11,12] however, they provide no information concerning an individual's levels of dynamic or static balance.

There are also a number of field and laboratory tests which measure balance and are proven indicators for falls probability and occurrence.[13-16] These tests, however, each evaluate different types of balance. For example, force plate tests, such as the center of pressure test and time to boundary measurement, and field tests, like the one-leg stand test, assess static balance. Other tests, like the Tinetti Performance Oriented Mobility Test (POMA) test, the Timed Up and Go (TUG), and the Functional Reach (FR) are dynamic in nature, but fail to evaluate reactive balance. Dynamic posturography platforms, in contrast, provide both a disturbance of balance to which the patient must react and a quantification of the patient's capacity to react to that disturbance.

Receiver-operated characteristics (ROC) curves are commonly used to assess the sensitivity and specificity of tests. Sensitivity indicates the true positive rate, or the ability to detect a condition, such as fall probability, whereas specificity denotes the number of false positives found in the population by the test. A highly discriminant test would have high sensitivity and high specificity, being able to identify all those with the condition, while detecting false positives.

Given the need for early detection of increasing potential for falls, the goal of this study was to examine the capacity of a number of field and laboratory tests to detect fall risk in a sample of older independently-living, community-dwelling persons.

CHAPTER 2: METHODS

Participants

Participants were recruited from the University of Miami campus and surrounding communities using posted flyers and presentations. All potential participants completed a health status questionnaire and were included in the study if they had no neurological, cognitive, or musculoskeletal impairments that would affect balance; unstable chronic disease state; major depression; severe vestibular problems; severe orthostatic hypotension; or simultaneous use of cardiovascular, psychotropic and antidepressant medications. Additionally, potential subjects could not have been participating in a formal balance program within the past year. The University of Miami's Institutional Review Board approved the study. The procedures and risks were thoroughly explained to the participants, and their written consent was obtained. During the initial recruitment period, 72 men and women over the age of 60 volunteered for the study. Six participants were excluded from the study (four due to scheduling or personal conflicts and two due to illnesses). Physical characteristics of the participants who completed the study are presented in Table 1.

Procedures

The testing components were classified into field tests and laboratory tests. Participants were classified as a "faller" or "non-faller" based on self-reported falls. If a person reported one or more falls within the past year he or she was classified as a "faller." Of the persons reporting falls eight reported a single fall, six reported two falls, one reported four falls and one reported five falls. The field tests included the TUG[14], the One-Leg

Stand Test (OLS)[16], the FR[13], and the POMA.[17] The laboratory tests included a center of pressure (COP) test[18] and time-to-boundary (TTB) measurements on a force platform,[19] and dynamic posturography using the Proprio 5000[1].

Figure 1 presents the timeline used for the study. Following confirmation of their eligibility and completion of their informed consent forms, participants came to the laboratory on three separate days. Day one was a familiarization day during which anthropometric measurements were taken and participants practiced each balance test. Participants were given clear instructions concerning proper performance of each test. In addition, the order of the field tests was randomized at this time. The testing was conducted by undergraduate and graduate students, as well as staff physical therapists and exercise physiologists at the University of Miami. All researchers received comprehensive training on the proper administration of each test prior to the actual testing period and whenever possible the same researcher administered the test to each participant. Day two was the first testing day. The participants were tested using the POMA, force platform, and the Proprio 5000. Day three was the final testing day and included the TUG, FR, and OLS field tests, and a second trial of the POMA.

Testing

Field Tests

The testing procedures for the TUG [14], OLS [16], FR [13], and POMA [17] have been previously described in the literature. Two trials were performed for each test and the

[1] Perry Dynamics, 2810 N. Jasper Street, Decatur, IL. 62526

trial producing the best result was used for the statistical analyses. Given the subjective nature of the POMA, trials were performed on different days to allow assessment of between day reliability. Cronbach's alpha for the POMA between days was r = .793.

Laboratory Tests

Force Platform. The participant removed his or her shoes prior to testing. The participant was then asked to stand on the platform with both arms by his or her sides. The *x* (medial-lateral) foot placement on the platform was determined by measuring the biacromial distance and placing each foot one-half of that distance from the midline of the plate. The *y* (anterior/posterior) placement of the foot was determined by measuring the foot length and aligning the foot with half the length on either side of the plate's center line. The participant was instructed to look straight ahead while maintaining the quiet stance. He or she performed two sets of a parallel stance balance test with eyes open. Each set included three repetitions of 10 seconds in duration. Center of pressure and time-to-boundary data were collected for statistical analysis.

The Proprio 5000. The participants completed a dynamic balance test called the Standard Proprio Test on the Proprio 5000. The device's ultrasonic sensor belt was placed on the participant's waist with the transmitter positioned between the spinous processes of lumbar vertebra five (L5) and sacral vertebra one (S1). The participant was placed in a harness to ensure safety and then stood on the moveable platform with feet shoulder width apart (See Figure 2). The device incrementally increased the angle of the platform in random (lateral, up and down, anterior to posterior, clockwise, and counter clockwise) directions. The speed gradually increased from a setting of 1 to 10, with speed 1 being 0.22 rad/s and speed 10 being 2.20 rad/s. The maximum length of the test was preset by the manufacturer at 120 seconds, however, the test automatically stopped if the device detected a translational movement of 7.6cm in any direction within a single collection period of 0.25 seconds or 12.7cm in any direction, from the initial starting point. The sensor recorded data every 0.25 second (480 total readings during the two minute test) including the total inches of movement (anterior/posterior, superior/inferior, and lateral). The cumulative variable computed by the Proprio 5000 was the dynamic motion analysis (DMA) score. The DMA score is calculated by determining the three-dimensional sensor position during each frame of data collection and computing the difference between two successive frames throughout the trial. The movement distances are then added together to determine the DMA score. If the test stops before the two-minute time limit, a score of "three" is added to the total for each remaining 0.25 second time period that is not completed. Data from the Proprio 5000's ultrasonic sensor has been highly correlated with medial-lateral and superior-inferior movements of the center of mass during motion capture analysis.[20] The test was performed once, and the available data included: the DMA score (DMA), the average lateral ($TRAN_{LAT}$), anterior/posterior ($TRAN_{AP}$), up/down ($TRAN_{UD}$), flexion/extension (ROT_{FE}), lateral flexion (ROT_{LF}), and rotation (ROT_{ROT}) variables, and total time in seconds spent on the test (P_{TT}).

Statistics

Participants were divided into fallers and non-fallers based on the falls history characteristics previously mentioned. Receiver-operated characteristics (ROC) curves were used to compare the sensitivity, specificity, and significance of each field and laboratory test. Sensitivity was calculated by dividing the number of fallers correctly diagnosed by the number of true fallers, and specificity was calculated by dividing the number of participants diagnosed without falls by the number of true non-fallers. A one-way ANOVA analysis was used to test for between-group differences, and effect sizes were calculated for each test. SPSS for Windows, Version 17.0, statistical program (SPSS, Inc., Chicago, IL) was used for data analyses.

CHAPTER 3: RESULTS

ROC curves

Figure 3 provides examples of ROC curves for variables with strong (Figure 3a) and weak (Figure 3b) capacities to distinguish between fallers and non-fallers. The ROC curve analysis results are shown in Table 2. For the field tests, only the OLS and TUG had the capacity to distinguish fallers from non-fallers ($p = 0.002$ and 0.008, respectively).

Analyses of the laboratory tests showed fallers and non-fallers could be identified using a number of Proprio 5000 variables. These included: DMA ($p = 0.009$), P_{TT}, ($p = 0.005$), $TRAN_{LAT}$ ($p = 0.015$), ROT_{FE} ($p = 0.001$), ROT_{LF} ($p = 0.004$), and ROT_{ROT} ($p = 0.003$). Faller and non-faller status could not be determined using any of the force plate COP measurements. In contrast, the TTB_{Ysd_min} and TTB_{Ymean_min} variables did differentiate fallers from non-fallers ($p = 0.042$ and 0.029, respectively).

One-way ANOVA

The one-way ANOVA results are shown in Table 3. Analyses of the field tests revealed significant between-group differences for the OLS ($p = 0.002$), TUG ($p = 0.008$), and POMA balance ($p = 0.02$) and gait ($p = 0.044$) sections, with fallers showing consistently poorer performances.

Analyses of the laboratory tests revealed significant between-group differences in the Proprio 5000. The fallers produced significantly higher scores for the DMA ($p = 0.008$) and $TRAN_{LAT}$ ($p = 0.013$), and lower scores for P_{TT} ($p = 0.01$), ROT_{FE} ($p = 0.003$), ROT_{LF} ($p = 0.008$), and ROT_{ROT} ($p = 0.008$) variables. For the force plate measurements, there were no statistical differences in any of the COP measurements. Time-to-boundary analysis revealed a significantly lower score for fallers versus non-fallers in TTB_{Ysd_min} ($p = 0.047$).

Effect Sizes

Graphs illustrating the effect sizes for the field test and laboratory tests are presented in Figures 4 through 7. For the field tests, the OLS and TUG showed the largest effect sizes (0.93 and 0.79, respectively), whereas the POMA balance and gait sections revealed moderate effect sizes (0.68 and 0.59, respectively). Analyses of the laboratory tests revealed moderate to large effect sizes for DMA (0.79), P_{TT} (0.76), $TRAN_{LAT}$ (0.73), ROT_{FE} (0.88), ROT_{LF} (0.79), and ROT_{ROT} (0.79), whereas $TRAN_{AP}$ revealed a moderate effect size (0.46) and $TRAN_{UD}$ showed a small effect size (0.15). For the force plate measurements, all four COP variables, $EO_{X\ Max}$, $EO_{Y\ Max}$, $EO_{vX\ Max}$, and $EO_{vY\ Max}$, had very small effect sizes (0.03, 0.00, 0.02, and 0.04, respectively). Time-to-boundary analysis showed moderate effect sizes for TTB_{Ysd_min} (0.58) and TTB_{Ymean_min} (0.57) and small effect sizes for the TTB_{Xsd_min} (0.28) and TTB_{Xmean_min} variables (0.35).

CHAPTER 4: DISCUSSION

The purpose of this study was to examine the capacity of a number of field and laboratory tests to detect fall risk in a sample of older independently-living, community-dwelling persons. The main findings for the field tests using the ROC curve analyses indicated two tests, the OLS and TUG, had the capacity to distinguish fallers from non-fallers. ANOVA analyses mirrored these results and added the balance and gait portions of the Tinetti POMA as tools for distinguishing differences between fallers and non-fallers.

Our results showing that the OLS is a strong indicator of falls are similar to those reported in other studies employing community-dwelling participants, [16, 21, 22] as well as in a frail, older population.[23] In contrast, the OLS has also been show to be ineffective in detecting a significant difference between fallers and non-fallers in a healthy older population.[24]

Our finding that the TUG is a strong indicator of falls is consistent with previous studies showing that the TUG can discriminate between fallers and non-fallers in a community-dwelling population.[25,26] For example, while examining the TUG under three conditions, the TUG alone, the TUG while performing a math subtraction test, and the TUG while carrying a full cup of water, Shumway-Cook et al found the test to be a an appropriate measure for identifying individuals who are prone to falls.[25] Additionally, Chiu et al compared the TUG to other field tests and found that multiple fallers took the longest time to complete the test, and that the test could also distinguish participants who had suffered a single fall from non-fallers.[26] The TUG has also yielded consistently poorer performance for fallers versus non-fallers in frail, older individuals; and the test results have been shown to correlate well with measures of functional mobility in this population.[14, 23]

Comparisons of the results for the Tinetti POMA to those of other studies are complicated by the complex nature of the test and the number of modifications that occur in the literature.[27] Adding to the problem is the fact that although the ANOVA indicated that the POMA could distinguish between fallers and non-fallers, the effect size was small and the ROC analysis did not support either component's effectiveness to distinguish between the groups. The conflicting findings in our analyses are consistent with the diverse results found in the literature. The balance portion of the test has been shown in a number of studies to be capable of predicting falls in a healthy, older population.[22, 28] However, not all results support these findings. A study by Chiu, Au-Yeung and Lo showed similar low ROC curve areas for the POMA and the same capacity to distinguish single fallers from non-fallers using ANOVA as we have reported.[26] The authors hypothesized that the subjective nature of the analysis may have been responsible for these findings. The balance portion of the POMA has also been shown to be predictive of falls in a frail, nursing home population, although certain aspects of the test were not used as the researchers believed they might be too challenging for this population.[29] In contrast, two separate studies reported that the balance portion, as well as the whole POMA, did not have the ability to discriminate fallers from non-fallers in either community-dwelling older persons and nursing home residents.[30,31]

The main findings for the laboratory tests using the ROC curve analyses showed fallers and non-fallers could be identified using a number of Proprio 5000 variables including: DMA, P_{TT}, $TRAN_{LAT}$, ROT_{FE}, ROT_{LF}, and ROT_{ROT}, as well as two time-to-boundary variables, TTB_{Ysd_min} and TTB_{Ymean_min}. The ANOVA also revealed significant between-group differences for the Proprio 5000, with the fallers producing significantly higher scores for the DMA, and $TRAN_{LAT}$, and lower scores for P_{TT}, ROT_{FE}, ROT_{LF}, and ROT_{ROT} variables than non-fallers. In addition, time-to-boundary analysis revealed a significantly lower score for fallers versus non-fallers in the TTB_{Ysd_min} variable.

Our results for the Proprio 5000 DMA, P_{TT}, and $TRAN_{LAT}$ variables followed the patterns we expected, with lower DMA and PLAT scores for non-fallers due to their better ability to control the translational displacement of the sacral marker throughout the test period. However, the rotational variables showed a distinctly different pattern, as the fallers produced significantly lower scores than the non-fallers in these variables. While the cause of this apparent contradiction is unclear, one possible explanation is that an increased use of body joint segments, or an increase in the degrees of freedom (DOF), could have been a strategy employed by the non-fallers to react to the platform displacement and control the translational movements of the sacral marker. The sensorimotor system uses multiple degrees of freedom to allow different strategies for maintaining postural control, and the number of degrees of freedom used is most likely dependent on the complexity of the task, the degree of change in the environment, and the health of the individuals.[32] Davids et al state that skilled performers can freeze or unfreeze the DOF in the chain of movement as the task constraints change, whereas less skilled performers tend to rigidly fix DOF, showing weak adaptation and functionality.[33] In addition, when studying how young and older individuals adjust their postures in response to self-induced balance perturbations, results showed that a young performer stabilizes his or her ankle allowing the release of additional upper body DOF.[34] Since the literature indicates that aging and disease are associated with a loss of movement complexity and variability,[35] the increased ROT_{FE}, ROT_{LF}, and ROT_{ROT} values in our non-fallers may constitute an increase in DOF during an exploratory search for a more stable and efficient postural coordination mode.[36]

Our finding that the TTB_{Ysd_min} and TTB_{Ymean_min} variables could distinguish fallers from non-fallers differ slightly from those of van Wegen et al who found that older individuals demonstrate reduced spatio-temporal stability margins in both anterior–posterior and medio-lateral directions.[37] The fact that the TTB measures in our study were more effective than COP measures reflects the finding by these researchers that TTB measures provided additional information about possible differences in the anterior-posterior and medial-lateral sway positions that were not detected by the analysis of COP position and variability.[37] Once again, the reason for the greater capacity of this measurement to distinguish fallers from non-fallers may be due to increased DOF of the latter. When comparing young, active females with self-reported chronic ankle instability (CAI) to controls, Hertel et al reported that the CAI group produced lower standard deviations of the TTB minima, suggesting lower variability in the CAI group compared to the controls.[19] The researchers pointed out that although increased variability has been associated with neuromuscular dysfunction, a possible explanation for the decreased variability in the CAI participants may be due to a reduction in the use of available degrees of freedom and also the number of strategies available to accomplish postural control and maintain balance.[19] In addition, higher levels of variability may indicate subconscious compensatory measures by the individual.[33] These same principles may be an explanation for our results showing greater variability in healthy, older individuals classified as “non-faller” versus “faller.”

Our results also indicate a testing strategy that may be used when evaluating fall risk in an older population. Given that both the field and laboratory tests demonstrated the ability to detect fallers in the healthy, independently-living older population in our study, they may both be applied to a testing sequence. The field tests are inexpensive and require little equipment; therefore, they may be used as a preliminary screening tool to identify fallers. However, they do not have the capacity to measure specific directional balance decrements. In contrast, laboratory tests, such as the Proprio 5000, are able to identify fallers, as well as measure directional balance deficiencies and different strategies used by individuals to maintain balance. Therefore, a testing sequence beginning with simple field tests and progressing to the more sophisticated laboratory tests provides an efficient, cost-effective strategy that includes general screening and detailed information on fall risk.

Limitations

A limitation of this study was the use of self-reported falls which may be a less accurate measure than prospectively recalled falls as elderly participants often do not recall falls that occurred during periods of time within three to twelve months.[38]

Conclusions

A number of field and laboratory tests that evaluate different forms of balance proved to be capable of identifying fallers in a sample of older independently-living, community-dwelling persons. In addition, our results indicate that analysis of dynamic posturography and TTB data may require a different approach given the possibility that increases in these values, which would normally denote decreased levels of balance in younger persons, may be indicative of balance strategies employing greater degrees of freedom in an older population. Future studies should examine these field and laboratory tests in an older population with an increased fall risk, as well as prospective studies, which follow people across time to measure the relationship between the number of falls and the scores produced during the testing battery. Additionally, lower and upper thresholds indicative of successful strategies and loss of stability, respectively, should be developed his population. And finally, we suggest using these data to develop balance training programs that concentrate on increasing the degrees of freedom used by older persons to maintain balance and recover from a stumble or other situation that can lead to a fall.

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FIGURES

Figure 1. Flowchart showing events across testing days.

Day 1
Informed Consent 15 minutes
HSQ 15 minutes
Randomization of Tests 1 minute
Anthropometric Measurements 5 minutes
Familiarization: Tests 1-6 30 minutes

Day 2
Tinetti POMA 15 minutes
Force Platform 10 minutes
Proprio 5000 10 minutes

Day 3
Timed Up and Go *(randomized)* 10 minutes
Rest Period: 5 minutes
Functional Reach *(randomized)* 10 minutes
Rest Period:7 minutes
One-Leg Stand *(randomized)* 10 minutes
Rest Period:10 minutes
Tinetti POMA *(randomized)* 10 minutes

Figure 2. Subject performing the Proprio 5000 test.

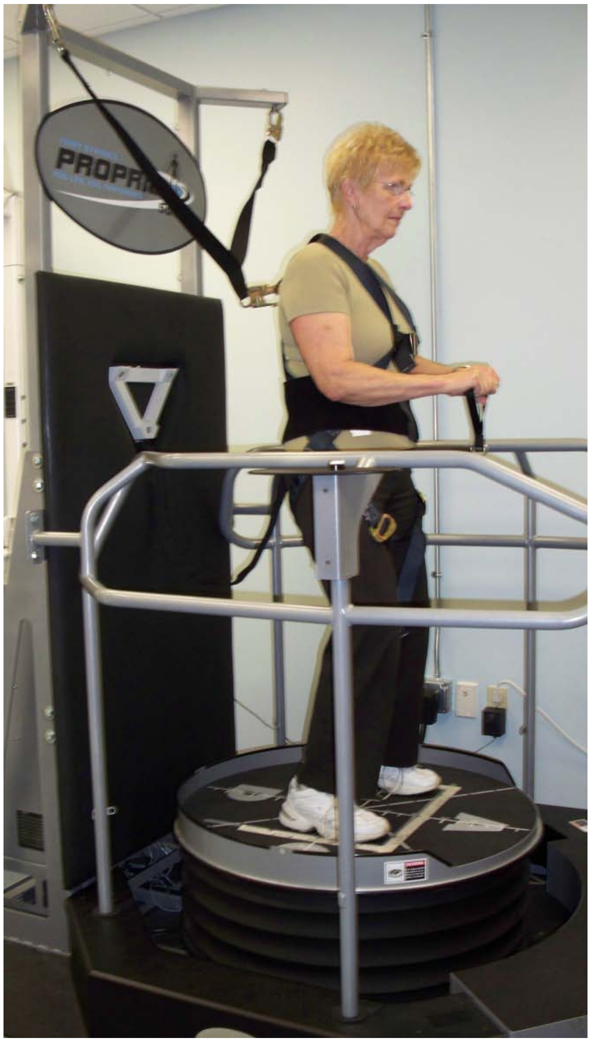


Figure 3. ROC curves for the One-Leg Stand (a) and Functional Reach (b) tests illustrating strong and weak capacities to distinguish fallers from non-fallers.

Figure 3a. One-Leg Stand

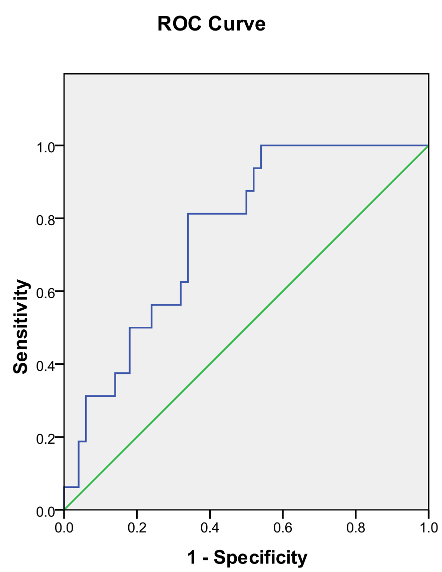


Figure 3b. Functional Reach

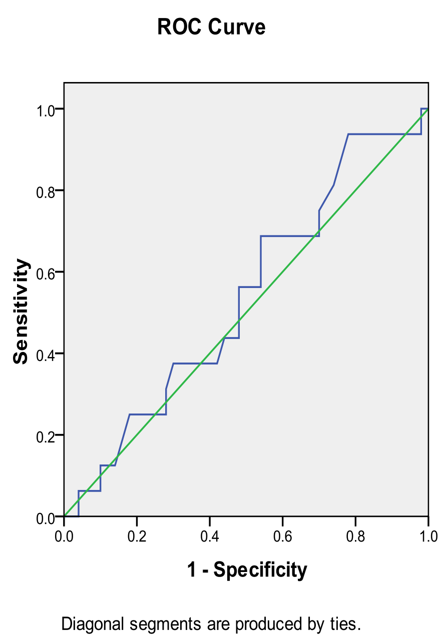


Figure 4. Graph showing effect size and 95% Confidence intervals for field tests. TUG = Timed Up and Go Test, OLS = One-Leg Stand Test, FR = Functional Reach Test, and TING and TINB are the gait and balance components of the Tinetti Performance Oriented Mobility Assessment (POMA).

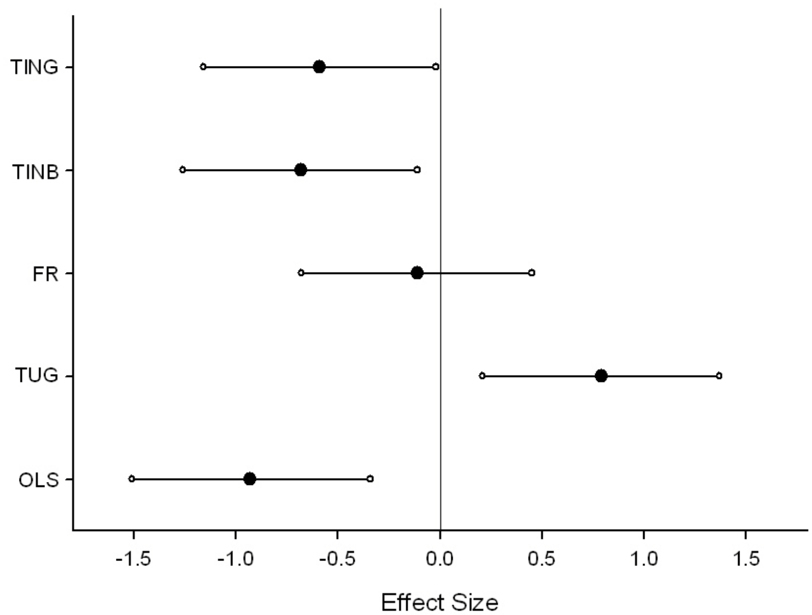


Figure 5. Graph showing effect size and 95% Confidence intervals for Proprio 5000 variables. DMA = DMA score, $TRAN_{LAT}$ = the average lateral, $TRAN_{AP}$= anterior/posterior, $TRAN_{UD}$ = up/down, ROT_{FE} = flexion/extension, ROT_{LF} = lateral flexion, ROT_{ROT} = rotation and P_{TT} = total time in seconds spent on the test.

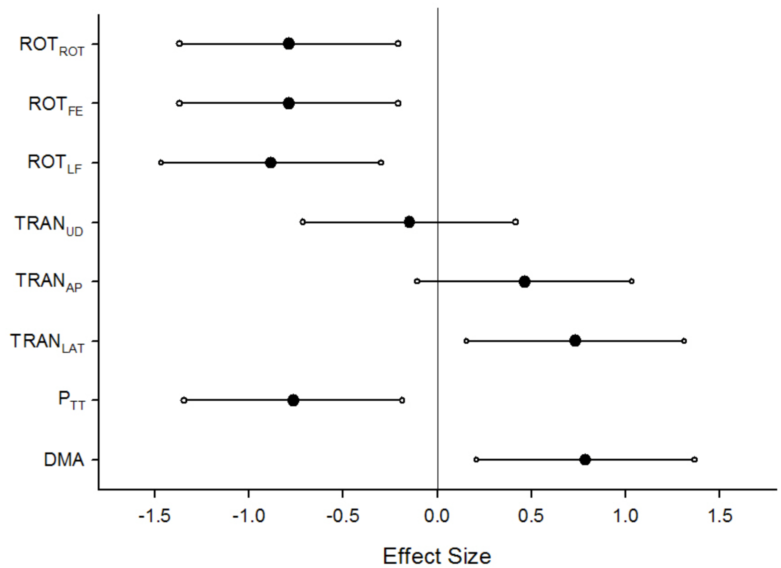


Figure 6. Graph showing effect size and 95% Confidence intervals for force platform center of pressure test variables. $EO_{X\ Max}$ = maximum lateral excursion, $EO_{Y\ Max}$ = maximum anterior/posterior excursion, $EO_{vX\ Max}$ = maximum lateral velocity and $EO_{vY\ Max}$ = maximum anterior/posterior velocity.

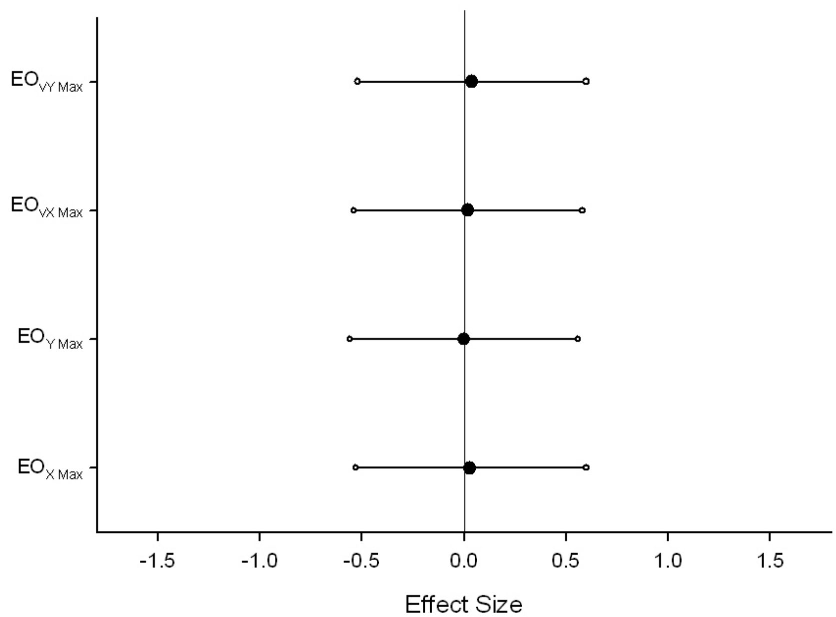
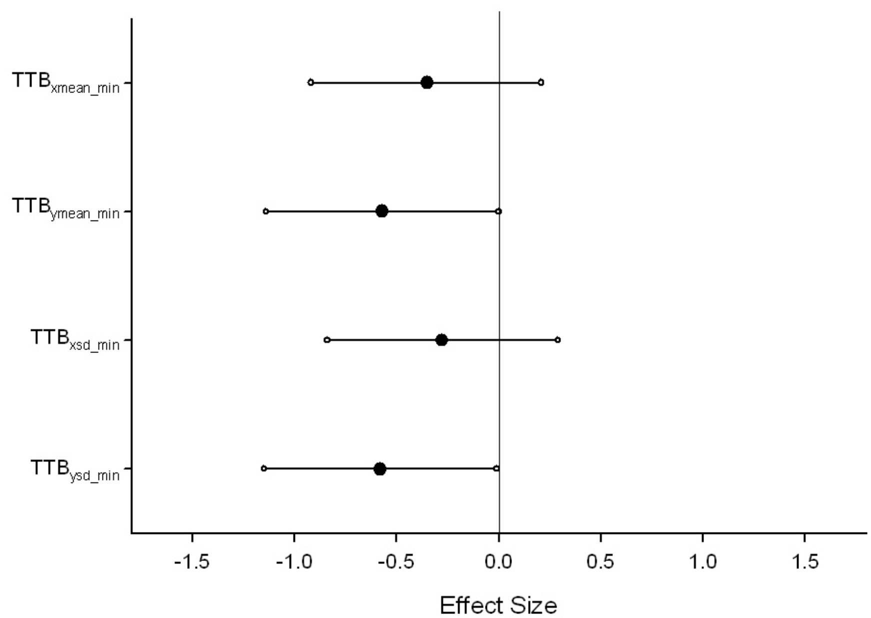


Figure 7. Graph showing effect size and 95% Confidence intervals for Time to Boundary test. TTB_{Ysd_min} = standard deviation of minimum anterior/posterior displacement, TTB_{Ymean_min} = mean minimum anterior/posterior displacement, TTB_{Xsd_min} = standard deviation of minimum lateral displacement, TTB_{Xmean_min} = mean minimum lateral displacement.



TABLES

Table 1. Physical Characteristics of Participants

Variable	Sample n=66	Fallers n=16	Non-fallers n=50
Age (yr)	72.0 ± 7.3	74.8 ± 5.6	71.1 ± 7.6
Height (cm)	151.7 ± 47.2	164.0 ± 10.0	166.0 ± 10.7
Mass (kg)	69.5 ± 26.3	78.1 ± 16.1	75.1 ± 16.7
Body mass index	27.6 ± 5.1	28.9 ± 5.2	27.2 ± 5.0

Values are mean (SD); n = 66.

Table 2. ROC curve results

Field Tests

Variables	Area	Sig	Threshold	Sensitivity	1-Specificity	Pos LR	Neg LR
OLS	0.760	0.002	3.420	0.313	0.140	2.236	0.799
FR	0.536	0.664	10.875	0.063	0.040	1.575	0.976
TUG	0.720	0.008	8.285	0.688	0.240	2.867	0.411
TINB	0.586	0.302	14.500	0.250	0.080	3.125	0.815
TING	0.546	0.580	10.500	0.250	0.040	6.250	0.781

Laboratory Tests

Variables	Area	Sig	Threshold	Sensitivity	1-Specificity	Pos LR	Neg LR
$EO_{X\ Max}$	0.548	0.565	0.380	0.313	0.180	1.739	0.838
$EO_{Y\ Max}$	0.527	0.748	0.910	0.313	0.160	1.956	0.818
$EO_{vX\ Max}$	0.478	0.788	4.070	0.250	0.060	4.167	0.798
$EO_{vY\ Max}$	0.545	0.590	-2.130	0.375	0.120	3.125	0.710
TTB_{Ysd_min}	0.670	0.042	3.232	0.250	0.020	12.500	0.765
TTB_{Xsd_min}	0.563	0.454	14.201	0.250	0.140	1.786	0.872
TTB_{Ymean_min}	0.683	0.029	9.594	0.500	0.220	2.273	0.641
TTB_{Xmean_min}	0.608	0.190	20.836	0.250	0.020	12.500	0.765
DMA	0.718	0.009	985.500	0.375	0.082	4.573	0.681
P_{TT}	0.735	0.005	45.650	0.375	0.102	3.676	0.696
$TRAN_{LAT}$	0.703	0.015	753.350	0.313	0.102	3.069	0.765
$TRAN_{AP}$	0.647	0.079	617.550	0.125	0.041	3.049	0.912
$TRAN_{UD}$	0.487	0.879	460.800	0.063	0.020	3.150	0.956
ROT_{FE}	0.226	0.001	470.150	0.063	0.041	1.537	0.977
ROT_{LF}	0.257	0.004	312.700	0.063	0.082	0.768	1.021
ROT_{ROT}	0.249	0.003	455.650	0.063	0.020	3.150	0.956

Table 3. One-Way ANOVA results

Field Tests

Variable	Type	Mean	SD	N	F	Sig
OLS	Faller	7.21	5.28	16	10.43	0.002
	Non-Faller	23.81	20.24	50		
TUG	Faller	8.96	1.49	16	7.62	0.008
	Non-Faller	7.60	1.78	50		
FR	Faller	14.46	2.50	16	0.15	0.699
	Non-Faller	14.78	2.90	50		
TINB	Faller	14.63	2.87	16	5.73	0.020
	Non-Faller	15.70	0.81	50		
TING	Faller	11.19	1.60	16	4.22	0.044
	Non-Faller	11.74	0.6	50		

Laboratory Tests

Variable	Type	Mean	SD	N	F	Sig
DMA	Faller	904.00	136.56	16	7.49	0.008
	Non-Faller	798.73	132.60	49		
P_{TT}	Faller	55.68	14.78	16	7.03	0.010
	Non-Faller	66.34	13.67	49		
$TRAN_{LAT}$	Faller	675.92	136.52	16	6.50	0.013
	Non-Faller	565.94	153.73	49		
$TRAN_{AP}$	Faller	502.99	96.79	16	2.60	0.112
	Non-Faller	458.75	94.78	49		
$TRAN_{UD}$	Faller	253.93	81.73	16	0.26	0.612
	Non-Faller	301.36	367.17	49		
ROT_{FE}	Faller	220.76	103.92	16	9.39	0.003
	Non-Faller	326.02	123.69	49		
ROT_{LF}	Faller	147.33	57.60	16	7.48	0.008
	Non-Faller	198.62	67.29	49		
ROT_{ROT}	Faller	193.37	108.2	16	7.47	0.008
	Non-Faller	273.39	99.46	49		

TTB_{Ysd_min}	Faller	5.88	2.36	16	4.11	0.047
	Non-Faller	7.80	3.53	50		
TTB_{Xsd_min}	Faller	20.74	6.62	16	0.93	0.338
	Non-Faller	24.72	15.95	50		
TTB_{Ymean_min}	Faller	10.13	4.10	16	3.90	0.052
	Non-Faller	13.57	6.54	50		
TTB_{Xmean_min}	Faller	36.38	12.85	16	1.52	0.221
	Non-Faller	45.69	29.13	50		

$EO_{X\ Max}$	Faller	0.33	0.18	16	0.00	0.970
	Non-Faller	0.32	0.32	50		
$EO_{Y\ Max}$	Faller	0.79	0.40	16	0.00	0.971
	Non-Faller	0.79	0.64	50		
$EO_{vX\ Max}$	Faller	3.07	1.32	16	0.00	0.954
	Non-Faller	3.04	1.61	50		
$EO_{vY\ Max}$	Faller	-2.88	1.17	16	0.01	0.893
	Non-Faller	-2.93	1.20	50		