Postural Control in Young People with Visual Impairments and Various Risks of Falls

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Structured abstract: *Introduction:* Early diagnosis of postural control deficiencies facilitates implementation of an individual rehabilitation plan to prevent falls. The aim of the study was to assess the risk of falling in individuals with visual impairments, and to compare performance-based and theoretical limits of stability in subjects with various risks of falling. *Methods:* The study was comprised of 23 participants with severe visual impairments. The risk of fall was assessed with the Step Test. Performance-based limits of stability were measured with the Advanced Mechanical Technology, Inc. (AMTI) platform, and theoretical limits of stability were calculated based on the height of the center of mass (COM) and maximum body sway leaning angles. *Results*: COM displacement values, corresponding to performance-based limits of stability, in individuals with visual impairments whose risk of falling was classified as high were significantly lower than the theoretical values ($p \leq .05$). Similar differences were not observed in participants with visual impairments whose risk of falling was assessed as low. Individuals from the low-risk group showed significantly higher values of performance-based limits of stability than the participants from the high-risk group ($p \leq .01$ for medio-lateral direction and $p \leq .05$ for forward-backward direction). *Discussion:* Nearly half of young people with visual impairments are at increased risk of falling. Such persons showed lower performance-based limits of stability than participants with visual impairments with a low risk of falling. Performance-based limits of stability in individuals with visual impairments with a high risk of falling are lower than their theoretical limits of stability. *Implications for practitioners*: The fact that nearly half of young people with visual impairments are at an increased risk of falling necessitates implementation of preventive measures in this group, as well as among individuals who are blind.

Early and accurate diagnosis of postural control deficiencies facilitates development of an effective therapeutic intervention and implementation of an individual rehabilitation plan to prevent falls. The vast majority of published papers dealing with the problem of falls refer to older persons. Previous research centered around the identification

of efficient methods to detect individuals at increased risk of falling (Park, Jung, & Kweon, 2014; Vance, Healy, Galvin, & French, 2015), fall-risk assessment in the elderly (Rogers, Rogers, Takeshima, & Islam, 2003; Stone, Skubic, Rantz, Abbott, & Miller, 2015), and the effectiveness of training and physiotherapy programs for the improvement of balance and fall prevention (Pata, Lord, & Lamb, 2014; Saeko et al., 2013).

The risk of falling is not limited solely to older persons, however; it also applies to younger subjects who have various conditions associated with body instability, such as Parkinson's disease (Brown et al., 2006; Vance et al. 2015), multiple sclerosis (Cameron, Horak, Herndon, & Bourdette, 2008; Nilsagård, von Koch, Nilsson, & Forsberg, 2014), neurological disorders (Salsabili, Bahrpeyma, Forogh, & Rajabali, 2011), and sensory disorders (Ivers, Cumming, Mitchell, & Attebo, 1998; Schmid, Nardone, De Nunzio, Schmid, & Schieppati, 2007).

The risk of falling may increase considerably due to visual impairments. The results of previous studies analyzing postural stability of people who are visually impaired imply that the loss of vision exerts detrimental effects on postural control (Giagazoglou et al., 2009; Ray & Wolf, 2008). The inability to use visual information lowers postural stability and prevents the visual assessment of one's own body position in space (Friedrich et al., 2008; Giagazoglou et al., 2009). As a result, people with visual impairments experience serious difficulties while executing motor activities and avoiding obstacles (Nakata & Yabe, 2001; Schmid et al., 2007). Previous studies that have assessed the risk of falling in individuals who are visually impaired have only investigated the older population (Evans et al., 2002; Ivers et al., 1998; Poulain & Giraudet, 2008). Available evidence suggests that older people with visual impairments are particularly exposed to the risk of falling (Anand, Buckley, Scally, & Elliott, 2003; Brooke-Wavell, Perrett, Howarth, & Haslam, 2002). It is of note, however, that visual impairment is only one of many factors contributing to postural stability disorders in this group (Dhital, Pey, & Stanford, 2010; Rogers et al., 2003). All persons who are visually impaired, irrespective of their age, experience difficulties in moving without assistance, and are more prone to lose balance. These problems are related to total or partial loss of vision.

Posturographic examination provides valuable data for the risk of fall assessment. In this context, the measurement of the center of pressure (COP) displacement during maximal voluntary body leaning is particularly important, as it determines one's limits of stability (LOS) (Błaszczyk, Hansen, & Lowe, 1993; Melzer, Benjuya, & Kaplanski, 2004; Woollacott & Shumway-Cook, 1996). LOS are closely linked to the maximal body leaning from vertical position that can be tolerated without the loss of stability. They determine an area within which one is able to adjust COP displacement without changing the supporting plane (that is, using ankle strategy and hip strategy). LOS can be also determined by theoretical calculations, without using posturographic measurements. Theoretical LOS computed based on maximum leaning angles were established in a group of

healthy, sighted adults. Although theoretical LOS are adjusted for subjects' anthropometric characteristics, neither age nor health and the potential deviations thereof are considered (Jbabdi, Boissy, & Hamel, 2008; NeuroCom International, 2002). Published evidence suggests that older persons and individuals with some pathological conditions such as Parkinson's disease do not reach their theoretical LOS during posturographic examination (Jbabdi et al. 2008; van Wegen, van Emmerik, Wagenaar, & Ellis, 2001).

To the best of our knowledge, the risk of falling has not been assessed in young people who are visually impaired thus far, and none of the previous studies analyzed potential differences in theoretical and actual—that is, posturographically determined—LOS in this group. Therefore, the aim of this study was to assess the risk of falling in young persons who are visually impaired, and to compare their performance-based and theoretical LOS.

We hypothesized that due to the lack of visual information, the performance-based LOS of persons who are visually impaired are lower than their theoretical LOS. Moreover, we expected that participants with visual impairments with a high risk of falling may show significantly lower values of performance-based LOS than individuals who are visually impaired with a low risk of falling.

Methods

Participants

The study was comprised of 23 individuals with severe visual impairments (15 women and 8 men, mean age: 32.4, *SD* 5.6 years), with a visual acuity of 0.1 to 0.05 (World Health Organization [WHO], 2010), free from other comorbidities. The severity of vision loss was assessed based on an ophthalmological examination. All participants were recruited from the Polish Association of the Blind. The protocol of the study was approved by the Local Bioethics Committee at Karol Marcinkowski University School of Medical Sciences in Poznan (decision no. 561/11), and written informed consent to participate was sought from all the study subjects.

Risk of falling assessment

The risk of falling was assessed with the Step Test (Hill, Bernhardt, McGann, Maltese, & Berkovits, 1996), based on the number of completed cycles of putting down and picking up the foot of one lower limb on a 7.5-inch step within 15 seconds. The Step Test is a reliable, validated clinical instrument for fall risk assessment. Sensitivity and specificity of this test in older persons were estimated at 85% and 88–100%, respectively, and its positive predictive value was estimated at 86% (Dite & Temple, 2002).

The test was conducted by a physiotherapist experienced in working with persons who are visually impaired. Prior to the test, the subjects were familiarized with its procedure and all necessary instruments. Two groups were identified, based on the outcome of the Step Test and reference values proposed by Isles, Choy, Steer, and Nitz (2004), according to whom the results below 18 discriminate the risk of falling in healthy adults:

- The high-risk group, comprised of 12 persons who are visually impaired with the Step Test results below 18; and

Table 1
Descriptive statistics and the results of ANOVA for somatic characteristics and the Step Test results in a group of people with visual impairments with low and high fall risk.

Variable	Fall risk group	Min–max	Mean (*SD*)	95% IC	$F_{(1, 21)}$ (*p*)	η^2
Body mass [kg]	High	48.00–110.00	70.42 (22.72)	55.98–84.85	0.16 (.715)	.01
	Low	53.00–117.00	73.54 (17.31)	61.91–85.18		
Body Height [cm]	High	140.50–200.00	170.58 (15.99)	160.43–180.74	0.45 (.510)	.02
	Low	151.00–188.00	166.68 (11.32)	159.07–174.28		
BMI [kg/m^2]	High	17.72–35.67	23.91 (5.81)	20.22–27.60	1.25 (.276)	.06
	Low	21.59–33.10	26.31 (4.27)	23.44–29.17		
Step Test	High	13.00–17.00	15.67 (1.30)	14.84–16.49	42.32 (.000)	.66
	Low	18.00–28.00	21.45 (2.77)	19.59–23.32		

- the low-risk group, comprised of 11 persons with visual impairments whose results in the Step Test were equal to 18 or higher.

Somatic characteristics of subjects from the two groups and results of the Step Test are shown in Table 1.

Procedures

Determination of performance-based LOS

The test was conducted with the AccuGait System posturographic force plate (AMTI model PJB-101, Waterdown, MA). All measurements were taken with open eyes. Each measurement lasted for 60 seconds.

The test was conducted at a sampling rate of 100 Hz. Raw data were filtered out by order with a Chebyshev low-pass filter with a 10-Hz cut-off frequency (Ruhe, Fejer, & Walker, 2010). Then, the COM signal was isolated from the purified COP signal as previously described by Błaszczyk (2008). According to Stemplewski, Maciaszek, Osiński, & Szeklicki (2011), test-retest reliability for all parameters related to stability limits is high.

Test description

Immediately before taking the measurements, the participants were informed about the test procedures and were familiarized with the technique used to perform body sways on the posturographic force plate. Each participant performed the test three times. The measurement was started in a natural, relaxed upright position. At the instructor's command "lean forward as far as possible," the participant leaned forward as far as possible and then returned to the starting upright position. Then, using an analogous procedure, the participant leaned backward, to the left, and to the right, always as far as possible (Błaszczyk et al., 1993; Riley, Mitra, Stoffregen, & Turvey, 1997; Schieppati, Hugon, Grasso, Nardone, & Galante, 1994). The leanings were performed with an upright trunk, to the point at which the participant was still able to maintain balance without assistance and with no necessity to step forward. The points defining extreme COM positions were analyzed during maximal voluntary leaning of the body in two directions: forward-backward (FB) and medio-lateral (ML).

The following parameters related to COM leanings were assessed: performance-based

LOS(FB) [cm]; the distance between the maximum COM displacements in FB direction; and performance-based LOS(ML) [cm] (that is, the distance between the maximum COM displacements in ML direction).

Calculation of theoretical LOS

Theoretical LOS were calculated based on the height of COM and maximum body sway leaning angles (NeuroCom International Inc., 2002). Maximum body sway angles are determined under the assumption that COM in a stable upright position is located at approximately half of the person's height (COM height = 0.5527 × height) and its displacements are constrained inside an inverted cone, determined as extending 6.25 degrees in the anterior (forward) direction, 4.45 degrees in the posterior (backward) direction, and 8 degrees to each side (NeuroCom International Inc., 2002). In our study, theoretical LOS(FB) and theoretical LOS(ML) in cm were computed from the following equations:

$$\text{theoretical LOS(FB) [cm]} = \text{COM height} \times \text{TAN}(6.25°) + \text{COM height} \times \text{TAN}(4.45°); \text{ and}$$

$$\text{theoretical LOS(ML) [cm]} = 2 \times \text{COM height} \times \text{TAN}(8°)$$

Statistical analyses

Statistical analyses were carried out with STATISTICA 10.0 software (StatSoft Inc., Tulsa, OK). Statistical significance of all tests was defined as $p \leq .05$. Statistical significance of intergroup differences in somatic parameters and results of the Step Test in individuals with visual impairments with low and high risk of falling were verified with one-way analysis of variance (ANOVA) with "group" factor. The significance of differences in limits of stability in participants with visual impairments with high and low risk of falling was determined with two-way ANOVA with "LOS" factor (theoretical LOS, performance-based LOS) and "group" factor (low falling risk, high falling risk). After determination of interaction effect for the two-way model, Bonferroni post hoc tests were conducted to identify all potential inter- and intragroup differences.

Results

ANOVA for COM displacements in the front ML direction documented statistically significant interaction effect, $F_{(1,\ 42)} = 12.02$, $p \leq .001$, $\eta^2 = .22$ (see Figure 1). Statistically significant differences ($p \leq 0.01$) were found between theoretical LOS(ML) and performance-based LOS(ML) values for the high-risk group. COM displacement values in ML direction determined in this group were markedly lower than the theoretical values. Similar differences were not observed in the group of visually impaired persons with low risk of falling. Moreover, as shown on post hoc analysis, individuals from the low-risk group showed significantly higher values of performance-based LOS in ML direction than participants with high risk of falling ($p \leq .01$).

The same phenomenon was observed during examination in forward-backward direction, $F_{(1,\ 42)} = 6.88$, $p = .012$, $\eta^2 = .14$ (see Figure 2). Again, performance-based LOS(FB) in participants with visual impairments with high risk of falling turned out to be significantly lower than

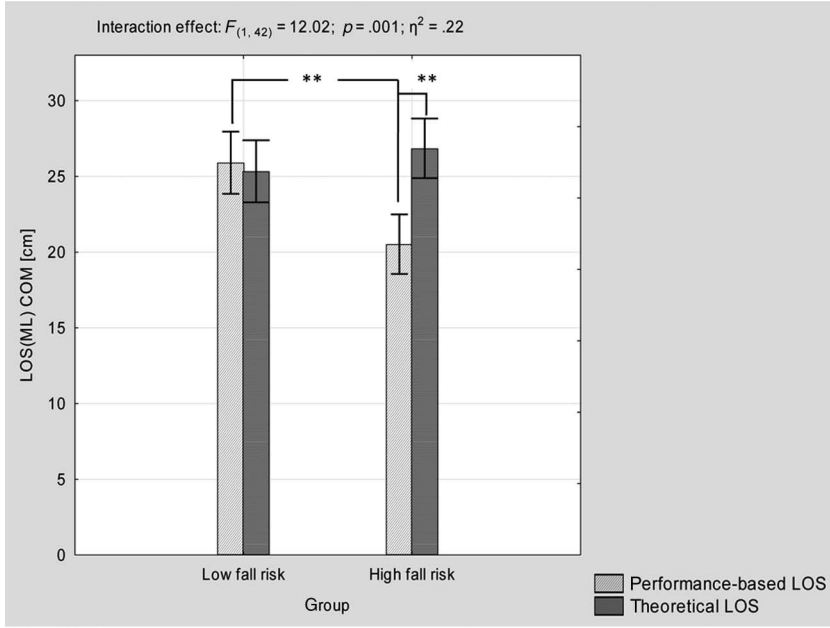

Figure 1. Mean values for limits of stability (LOS) in medio-lateral direction, along with the results of two-way ANOVA for the LOS factor (performance-based, theoretical) and group factor (low fall risk, high fall risk).

the theoretical LOS(FB) ($p = .01$). The statistically significant ($p \leq .05$) higher values of performance-based LOS in the low-risk group as compared to performance-based LOS in the high-risk group was observed.

Discussion

The aim of this study was to assess the risk of falling in young people with visual impairments, and to compare their performance-based and theoretical LOS.

A decrease in COP displacement during maximal voluntary body leaning is interpreted as a reduced level of postural stability and a marker of increased risk of falling (Błaszczyk et al., 1993). The area of COP displacement during maximal voluntary body leaning has been studied extensively in older persons (Błaszczyk at al., 1993; Holbein-Jenny, McDermott, Shaw, & Demchak, 2007). This parameter was shown to decrease with age and to correlate inversely with COP displacement in the coronal and sagittal planes during voluntary standing (Holbein-Jenny et al., 2007). Haibach, Lieberman, & Pritchett (2011) analyzed the area of COP displacement during maximal body leaning in young subjects with visual impairments. They showed that persons who are visually impaired showed significantly lower limits of stability than their sighted peers. However, no significant differences in LOS were found between persons who are visually impaired and blind.

The results of the Step Test conducted within the framework of our study imply that more than half of persons who are visually impaired may be at increased risk of falling. Importantly, the participants

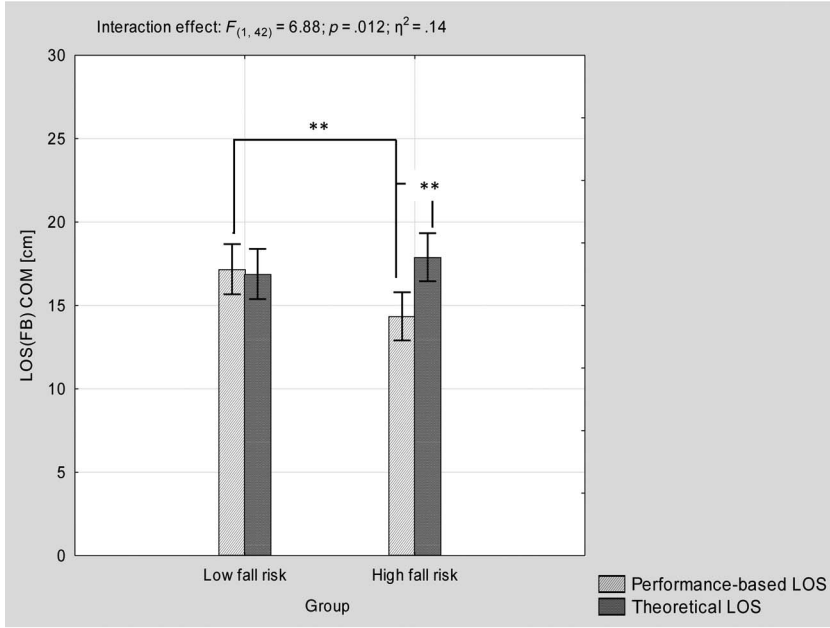

Figure 2. Mean values for limits of stability (LOS) in forward-backward direction, along with the results of two-way ANOVA for the LOS factor (performance-based, theoretical) and group factor (low fall risk, high fall risk).

whose risk of falling was classified as high on the basis of the Step Test showed significantly lower values of COM displacement during maximal body leaning than individuals from the low-risk group. Up to 75% of persons with visual impairments with a high risk of falling and only 27% of participants with visual impairments with a low risk did not reach their theoretical LOS during the measurement of COM displacement at maximal body leaning.

Fearn et al. (2010) used the same methodology to assess the risk of falling in individuals with hemophilia. Similar to our study, the results of the Step Test were consistent with posturographic findings. Individuals with hemophilia showed significantly lower LOS than healthy controls, and the results of the Step Test (mean 11.65) implied that they were also more prone to fall.

In this study, we compared actual performance-based LOS of individuals with high and low risk of falling with their theoretical LOS derived from leaning angles. Statistically significant differences between performance-based and theoretical LOS were found only in the high-risk group. In that group, performance-based LOS in both forward-backward and medio-lateral direction turned out to be significantly lower than respective theoretical LOS. During LOS posturographic measurements, people with visual impairments with a high risk of falling achieved 78% and 77% of their theoretical LOS in FB and ML directions, respectively. In turn, older persons participating in a study conducted by Jbabdi et al. (2008) reached 72% and 54% of their theoretical LOS in forward-backward and medio-lateral direction, respectively. It is

worth mentioning, however, that in the latter study, COP displacement area during maximal voluntary body leaning was determined with visual-motor feedback; that is, the subject was to move the point representing COP displacement to a strictly defined position.

One potential methodological limitation of this study seems to be the Step Test used for the risk of falling assessment, since the validity of this instrument has not been verified in participants with visual impairments thus far. However, to the best of our knowledge, no validated test exists for the risk of fall assessment in individuals who are visually impaired. Therefore, from a long list of instruments assessing the risk of falling, we have chosen an easy but still safe test as most suitable for people deprived of visual information. The results of this study should be interpreted with caution due to a considerable variance in subjects' BMI values. Further, every possible effort was made to eliminate potential confounding effects of age on the study findings.

Conclusion

Nearly half of young people with visual impairments are at increased risk of falling, which justifies implementation of respective preventive measures in this group. Individuals with visual impairments and increased risk of falling showed lower performance-based LOS than participants who were visually impaired from the low-risk group. During posturographic examination, a considerable fraction of persons from the former group were unable to reach their theoretical LOS derived from maximum leaning angles.

References

Anand, V., Buckley, J. G., Scally, A., & Elliott, D. B. (2003). Postural stability changes in the elderly with cataract simulation and refractive blur. *Investigative Ophthalmology & Visual Science, 44*(11), 4670–4675.

Błaszczyk, J. W. (2008). Sway ratio—A new measure for quantifying postural stability. *Acta Neurobiologiae Experimentalis, 68,* 51–57.

Błaszczyk, J. W., Hansen, P. D., & Lowe, D. L. (1993). Postural sway and perception of the upright stance stability border. *Perception, 22*(11), 1333–1341.

Brooke-Wavell, K., Perrett, L. K., Howarth, P. A., & Haslam, R. A. (2002). Influence of the visual environment on the postural stability in healthy older woman. *Gerontology, 48*(5), 293–297.

Brown, L. A., Cooper, S. A., Doan, J. B., Dickin, D. C., Whishaw, I. Q., Pellis, S. M., . . . Suchowersky, O. (2006). Parkinsonian deficits in sensory integration for postural control: Temporal response to changes in visual input. *Parkinsonism and Related Disorders*, *12*(6), 376–381.

Cameron, M. H., Horak, F. B., Herndon, R. R., & Bourdette, D. (2008). Imbalance in multiple sclerosis: A result of slowed spinal somatosensory conduction. *Somatosensory Motor Research, 25*(2), 113–122.

Dhital, A., Pey, T., & Stanford, M. R. (2010). Visual loss and falls: A review. *Eye, 24*, 1437–1446.

Dite, W., & Temple, V. A. (2002). A clinical test of stepping and change of direction to identify multiple falling older adults. *Archive of Physical Medicine and Rehabilitation, 83*(11), 1566–1571.

Evans, J. R., Fletcher, A. E., Wormald, R. P., Ng, E. S., Stirling, S., Smeeth, L., . . . Tulloch, A. (2002). Prevalence of visual impairment in people aged 75 years and older in Britain: Results from the MRC trial of assessment and management of older people in the community. *British Journal of Ophthalmology, 86*(7), 795–800.

Fearn, M., Hill, K., Williams, S., Mudge, L., Walsh, C., McCarthy, P., Walsh, M., & Street A. (2010). Balance dysfunction in adults with haemophilia. *Haemophilia, 16*(4), 606–614.

Friedrich, M., Grein, H. J., Wicher, C., Schuetze, J., Mueller, A., Lauenroth, A. K., . . . Schwesig, R. (2008). Influence of pathologic and simulated visual dysfunction on the postural system. *Experimental Brain Research, 186*(2), 305–14.

Giagazoglou, P., Amiridis, I. G., Zafeiridis, A., Thimara, M., Kouvelioti, V., & Kellis E. (2009). Static balance control and lower limb strength in blind and sighted women. *European Journal of Applied Physiology, 107*(5), 571–579.

Haibach, P., Lieberman, L., & Pritchett, J. (2011). Balance in adolescents with and without visual impairments. *Insight: Research & Practice in Visual Impairment & Blindness, 4*(3), 112–123.

Hill, K., Bernhardt, J., McGann, A., Maltese, D., & Berkovits, D. (1996). A new test of dynamic standing balance for stroke patients: Reliability, validity and comparison with healthy elderly. *Physiotherapy Canada, 48*, 257–262.

Holbein-Jenny, M. A., McDermott, K., Shaw, C., & Demchak, J. (2007). Validity of functional stability limits as a measure of balance in adults aged 23–73 years. *Ergonomics, 50*(5), 631–646.

Isles, R. C., Choy, N. L., Steer, M., & Nitz, J. C. (2004). Normal values of balance tests in women aged 20–80. *Journal of American Geriatric Society, 52*(8), 1367–1372.

Ivers, R. Q., Cumming, R. G., Mitchell, P., & Attebo, K. (1998).Visual impairment and falls in older adults: The Blue Mountains Eye Study. *Journal of American Geriatric Society, 46*(1), 58–64.

Jbabdi, M., Boissy, P., & Hamel, M. (2008). Assessing control of postural stability in community-living older adults using performance-based limits of stability. *BioMed Central Geriatrics, 31*, 8. doi: 10.1186/1471-2318-8-8.

Melzer, N., Benjuya, J., & Kaplanski, J. (2004). Postural stability in the elderly: A comparison between fallers and non-fallers. *Age and Ageing, 33*(6), 602–607.

Nakata, H., & Yabe, K. (2001). Automatic postural response systems in individuals with congenital total blindness. *Gait & Posture, 14*(1), 36–43.

NeuroCom International. (2002). *Balance Master operator's manual.* Clackamas, OR: Author.

Nilsagård, Y. E., von Koch, L. K., Nilsson, M., & Forsberg, A. S. (2014). Balance exercise program reduced falls in people with multiple sclerosis: A single-group, pretest-posttest trial. *Archive of Physical Medicine and Rehabilitation, 95*(12), 2428–2434.

Park, J. W., Jung, M., & Kweon, M. (2014). The mediolateral CoP parameters can differentiate the fallers among the community-dwelling elderly population. *Journal of Physical Therapy Science*, *26*(3), 381–384.

Pata, R. W., Lord, K., & Lamb, J. (2014). The effect of Pilates-based exercise on mobility, postural stability, and balance in order to decrease fall risk in older adults. *Journal of Bodywork and Movement Therapies, 18*(3), 361–367.

Poulain, I., & Giraudet, G. (2008). Age-related changes of visual contribution in posture control. *Gait & Posture, 27*(1), 1–7.

Ray, C. T., & Wolf, S. L. (2008). Review of intrinsic factors related to fall risk in individuals with visual impairments. *Journal of Rehabilitation Research & Development, 45*(8), 1117–1124.

Riley, M. A., Mitra, S., Stoffregen, T. A., & Turvey, M. T. (1997). Influences of body lean and vision on unperturbed postural sway. *Motor Control, 1*, 229–246.

Rogers, M. E., Rogers, N. L., Takeshima, N., & Islam, M. M. (2003). Methods to assess and improve the physical parameters associated with fall risk in older adults. *Preventive Medicine, 36*(3), 255–264.

Ruhe, A., Fejer, R., & Walker, B. (2010). The test-retest reliability of centre of pressure measures in bipedal static task conditions—A systematic review of the literature. *Gait & Posture, 32*(4), 436–445.

Saeko, I., Hiroyuki, U., Takefumi,' S., Kenichi, T., Masaru, M., & Yasuo, F. (2013). Effects of yoga therapy on postural stability in patients with schizophrenia-spectrum disorders: A single-blind randomized controlled trial. *Journal of Psychiatric Research, 47*(11), 1744–1750.

Salsabili, H., Bahrpeyma, F., Forogh, B., & Rajabali, S. (2011). Dynamic stability training improves standing balance control in neuropathic patients with type 2 diabetes. *Journal of Rehabilitation Research & Development, 48*(7), 775–786.

Schieppati, M., Hugon, M., Grasso, M., Nardone, A., & Galante, M. (1994). The limits of equilibrium in young and elderly normal subjects and in parkinsonians. *Electroencephalography & Clinical Neurophysiology, 93*(4), 286–298. doi:10.2478/v10078-011-0018-9

Schmid, M., Nardone, A., De Nunzio, A. M., Schmid, M., & Schieppati, M. (2007). Equilibrum during static and dynamic tasks in blind subjects: No evidence of cross-modal plasticity. *Brain, 130,* 2097–2107.

Stemplewski, R., Maciaszek, J., Osiński, W., & Szeklicki, R. (2011). Test-retest reliability of measurements of the center of pressure displacement in quiet standing and during maximal voluntary body leaning among healthy elderly men. *Journal of Human Kinetics, 28*, 15–23.

Stone, E., Skubic, M., Rantz, M., Abbott, C., & Miller, S. (2015). Average in-home gait speed: Investigation of a new metric for mobility and fall risk assessment of elders. *Gait & Posture, 41*(1), 57–62.

van Wegen, E. E., van Emmerik, R. E., Wagenaar, R. C., & Ellis, T. (2001). Stability boundaries and lateral postural control in Parkinson's disease. *Motor Control, 5*(3), 254–269.

Vance, R. C., Healy, D. G., Galvin, R., & French, H. P. (2015). Dual tasking with the timed "up & go" test improves detection of risk of falls in people with Parkinson's disease. *Physical Therapy,* 95(1), 95–102.

Woollacott, M., & Shumway-Cook, A. (1996). Clinical and research methodology for the study of posture and balance. In L. Sudarsky (Ed.), *Gait disorders of aging* (pp. 107–121). Philadelphia, PA: Lippincott-Raven.

World Health Organization. (2010). *International statistical classification of diseases and related health problems.* Retrieved from http://apps.who.int/classifications/icd10/browse/2010/en

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