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Fear of Falling and Gait Variability in Older Adults: A Systematic Review and Meta-Analysis

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A B S T R A C T

Background: Fear of falling (FOF) and increased gait variability are both independent markers of gait instability. There is a complex interplay between both entities. The purposes of this study were (1) to perform a qualitative analysis of all published studies on FOF-related changes in gait variability through a systematic review, and (2) to quantitatively synthesize FOF-related changes in gait variability.

Methods: A systematic Medline literature search was conducted in May 2014 using the Medical Subject Heading (MeSH) terms “Fear” OR “fear of falling” combined with “Accidental Falls” AND “Gait” OR “Gait Apraxia” OR “Gait Ataxia” OR “Gait disorders, Neurologic” OR “Gait assessment” OR “Functional gait assessment” AND “Self efficacy” OR “Self confidence” AND “Aged” OR “Aged, 80 and over.” Systematic review and fixed-effects meta-analysis using an inverse-variance method were performed.

Results: Of the 2184 selected studies, 10 observational studies (including 5 cross-sectional studies, 4 prospective cohort studies, and 1 case-control study) met the selection criteria. All were of good quality. The number of participants ranged from 52 to 1307 older community-dwellers (26.2%–85.0% women). The meta-analysis was performed on 10 studies with a total of 999 cases and 4502 controls. In one study, the higher limits of the effect size’s confidence interval (CI) were lower than zero. In the remaining studies, the higher limits of the CI were positive. The summary random effect size of 0.29 (95% CI 0.13 –0.45) was significant albeit of small magnitude, and indicated that gait variability was overall 0.29 SD higher in FOF cases compared with controls.

Conclusions: Our findings show that FOF is associated with a statistically significant, albeit of small magnitude, increase in gait variability.

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Gait disorders are highly frequent in adults aged 65 years and older with a prevalence estimated at approximately 35%.1-3 They may be separated into neurological and non-neurological disorders.1-3

Until recently, it was considered that neurological gait disorders result from focal to diffuse lesions occurring in the neural pathways linking the cortical motor centers to the peripheral neuromuscular systems.1-3 Nowadays, there is growing evidence that a part of neurological gait disorders is caused by impairment in the highest levels of gait control (ie, subcortical and cortical levels) without any brain lesion identifiable.1-3 For instance, it has been reported that individuals with neuropsychiatric disorders, such as anxiodepressive symptoms, have slower gait and are less steady when walking compared with healthy individuals.1-3

Fear of falling (FOF) is defined as the lack of self-confidence that activities of daily living may be performed without falling is a cause of cautious gait.3,10 FOF is common in older adults with a high prevalence estimated to be more than 20%3,10 and has been described as a cause of gait disorders due to impairment in cortical level of gait control.5 Most previous studies focused on unspecified FOF-related
changes in gait performance and reported mild-to-moderate slowing, reduced mean stride length, and widening of the base of support, whereas variability of gait parameters has been reported as a better phenotype of cortical gait control than mean values of spatio-temporal gait parameters.\textsuperscript{1–15}

Movement variability is a marker of motor coordination and reflects the control of the sensorimotor system.\textsuperscript{11,12} Variability represents a central issue for the study of motor control.\textsuperscript{13,14} It has been shown that gait variability, defined as the stride-to-stride fluctuations in walking, is a relevant marker of gait stability and cortical gait control.\textsuperscript{13–21} The general assumption is that there is an inverse association between gait variability and gait stability. Low gait variability reflects an efficient gait control and safe gait patterns.\textsuperscript{3,16–21} FOF-related increase in gait variability has been questioned.\textsuperscript{21,22} Studies reported mixed results, as some showed a significant association whereas others did not,\textsuperscript{22–24} underscoring a complex interplay between FOF and gait variability. Thus, the first question to better understand the relationship between these entities is to determine whether or not FOF may influence gait variability among older adults. No structured critical evaluation of previously published studies has been performed. A systematic review could be helpful to provide an answer to this question. The purposes of this study were (1) to perform a qualitative analysis of all published studies on FOF-related changes in gait variability through a systematic review, and (2) to quantitatively synthesize FOF-related changes in gait variability.

Methods

Literature Search

A systematic Medline literature search was conducted in May 2014 without restriction of date and language, using the Medical Subject Heading (MeSH) terms “Fear” OR “fear of falling” combined with “Accidental Falls” AND “Gait” OR “Gait Apraxia” OR “Gait Ataxia” OR “Gait disorders, Neurologic” OR “Gait assessment” OR “Functional gait assessment” AND “Self efficacy” OR “Self confidence” AND “Aged” OR “Aged, 80 and over.” An iterative process was used to ensure all relevant articles had been obtained. A further hand search of bibliographic references of extracted papers and existing reviews was also conducted to identify potential studies not captured in the electronic database searches.

Study Selection and Analysis

Titles and abstracts of identified references were screened by a member of the team (FA) and obtained articles deemed potentially relevant. Initial screening criteria for the abstracts were as follows: (1) article written in English or French; (2) involvement of human participants aged 65 and older; (3) absence of neurological, rheumatologic, and ocular diseases; (4) observation and intervention studies (cohort, case-control, and cross-sectional studies were included); (5) FOF and gait as outcomes; and (6) quantitative measures of spatio-temporal gait parameters using biomechanical methods for assessment (eg, electronic walkways, footswitches systems). Studies that used only a questionnaire or the Time Up and Go test or another clinical test for gait assessment were excluded. If a study met the initial selection criteria or its eligibility could not be determined from the title and abstract, the full text was retrieved. A second study screening was performed. The full text was assessed for inclusion status. In case of disagreements, the articles were discussed with 2 of the authors (OB and CA). Final selection criteria were applied when gait variability was an outcome, or alternatively when the association between FOF and gait variability was examined. The study selection is shown on a flow diagram (Figure 1).

Of the 2184 originally identified abstracts, 199 (9.1\%) met the initial inclusion criteria (see Appendix 1). Following thorough examination, we excluded 189 (94.9\%) of those 199 studies because gait variability or the association between FOF and gait variability was not an outcome. The remaining 10 studies were included in this review.\textsuperscript{6,10,21–28} The quality of each study was assessed using the Newcastle–Ottawa Scale,\textsuperscript{28} a validated technique for assessing the quality of case-control and nonrandomized cohort studies. The instrument uses a star system to evaluate observational studies based on 3 criteria: participant selection, comparability of study groups, and assessment of outcome or exposure (see Appendix 2). Articles selected for the full review had the following information extracted: authors, date of publication, study design, settings and study population, assessment methods of FOF and gait, gait variability (ie, SD or coefficient of variation [CoV] of gait parameters), and result of the association between FOF and gait variability (Supplementary Table 1).

Definition of Outcomes

We examined gait variability as measured by the SD or CoV of stride time or stride length, as these measures are generally accepted as reliable indicators of the control of the walking-related rhythmic stepping mechanism.\textsuperscript{11,18–20} When a study reported these parameters, only stride time variability was used for meta-analysis, because this gait parameter was reported to be the best biomarker of cortical gait control.\textsuperscript{12–16} Low variability values of both of these spatio-temporal gait parameters reflect the reliability of limb movements and the automated regular rhythmic feature of gait and are associated with safe gait.\textsuperscript{11,12} The study population of cases was estimated as the number of participants with FOF, regardless of the severity, duration, or management of the FOF. Controls presented no FOF. For this purpose, in the study of Herman et al,\textsuperscript{6} we considered the group of patients with high-level gait disorders as the group of participants with FOF and the group of controls as those without FOF. Indeed, selected participants in this study were free of morbidities able to influence gait variability. They had self-reported walking difficulties that could not be attributed to any specific disease or medical condition.

Meta-analysis

All results were expressed in terms of a bias-corrected “effect size” of the difference between gait variability in cases and controls. Because mean value and SD of stride time was not provided in 3 articles, a request was successfully formulated to the first authors.\textsuperscript{26,28} An effect size calculator worksheet was used to derive bias-corrected effect sizes from mean, SD, and size of each group (Coe’s Calculator retrieved November 16, 2013, from http://www.cemcentre.org/evidence-based-education/effect-size-calculator). Qualitative descriptors of the effect sizes obtained were less than 0.3, small; 0.4 to 0.8, moderate; and greater than 0.8, large.\textsuperscript{29} Individual study data were then pooled using an inverse-variance method. Heterogeneity between studies was assessed using Cochran’s chi-squared test for homogeneity (Chi2), and amount of variation due to heterogeneity was estimated by calculating the I\textsuperscript{2}.\textsuperscript{27} As heterogeneity was invariably high, fixed but also random-effects meta-analyses were performed on the estimates to generate summary values (Review Manager version 5.1; The Nordic Cochrane Centre, Copenhagen, Denmark). Results are presented as a forest plot.

Results

All studies were judged of good quality using the Newcastle-Ottawa Scale (see Appendix 2). Supplementary Table 1 summarizes the 10 studies included in this review and meta-analysis.\textsuperscript{6,10,21–28} Data
collection was based on cross-sectional design for 5 studies,8,21,22,27,28 on prospective observational cohort design for 4 studies,23,24,26 and on case-control design for 1 study.6 Population ranged from 524 to 1307,26 and was most frequently female with a prevalence ranging from 26.2%10 to 85.0%.26 The mean age ranged between 68.0 ± 1.4 and 82.0 ± 6.0 years.23 Different methods were used to assess FOF. The most frequent (80.0%, n = 8) was the use of a single question “Are you afraid of falling?” with a binary answer (ie, yes or no).10,21,24,26,28 Falls efficacy scale (FES) was used in 2 studies21,24 and activities specific balance confidence scale (ABC) in 3 other studies.6,10,25 Most studies examined gait variability using CoV of stride time,6,10,21,22,25,28 whereas others used SD.5,23,24 Other studies examined variability of stride length,10,21,26 stride velocity,21,23 double-support time,24 and swing time24 measured with different types of devices including footswitches system, Physilog system (BioAGM, CH, Geneva, Switzerland) or GAITRite system (CIR Systems, Sparta, NJ), and wireless motion recording sensor units. Four studies found significant higher gait variability in individuals with FOF compared with those without FOF.6,25,27,28 Two studies showed an inconclusive result,23,26 and 4 studies reported mixed results.10,21,22,24 In the latter case, a prospective cohort study observed that FOF evaluated by the single question was not associated with gait variability, whereas FES score was positively associated with gait variability.24 Another prospective cohort study showed significant association with stride time but not with stride length.10 A cross-sectional study also reported mixed results, as FOI without activity restriction was not associated with gait variability, whereas FOI with activity restriction was.21 In addition, our previous original study showed that higher stride time variability was significantly associated with FOI in people with history of falls, but no association was reported in people without history of falls.22

For ease of interpretation, a meta-analysis was performed on 10 studies identified in systematic review with a total of 999 cases and 4502 controls (Figure 2). For 3 studies, samples were separated into 4 subgroups21,22,26 according to FOI, and then according to activity restriction21,26 or history of falls.22 All effect sizes but one calculated at –0.7124 were positive and ranged from 0.05 to 1.28 (see Appendix 3), on a scale where 0 corresponded to no difference between cases with FOI and controls without FOI, and negative effect sizes indicated that cases have higher (ie, worse) gait variability than controls. In one study, the higher limits of the effect size’s confidence interval (CI) were lower than zero.24 In the remaining studies, the higher limits of the CI were positive. The summary random effect size of 0.29 (95% CI 0.13–0.45)
indicated that gait variability was overall 0.29 SD higher in FOF cases compared with controls without FOF (Figure 2). This represents a "small" association of high gait variability with FOF. Using the "Common Language Effect Size" approach of McGraw and Wong, the probability is approximately 29% that an individual without FOF would have lower (ie, better) gait variability than an individual with FOF if both individuals were chosen at random from a population.

Discussion

This systematic review and meta-analysis shows that FOF is associated with a small, significant increase in gait variability (ie, worst performance of gait). In addition, mixed results of qualitative analysis suggest that this association may be influenced by other covariables that should be taken into account when examining it.

Four studies of the 10 selected have shown a significant FOF-related increase in gait variability. In these studies, FOF was assessed either by the ABC score of specific balance confidence scale or by a single question with a dichotomous statement (yes versus no). Gait was assessed using 2 different gait analysis systems: footswitches and wireless motion recording sensor units. Gait measurement by wireless motion recording sensors units were performed by using a triaxial accelerometer, providing precise and accurate measurements of gait cycle parameters. For instance, Greene et al showed that algorithms for body-worn sensors are comparable to the GAITRite electronic walkway for measurement of spatiotemporal gait parameters in healthy individuals. Similarly, it has been shown that the level of agreement between footswitches system and GAITRite system is high, confirming that they provide similar measures of stride time variability. Thus, we can consider that measures of gait variability of the footswitches system and the wireless motion recording sensor units are comparable.

The fact that FOF may induce changes in gait performance has been previously reported, but in contrast to our study, reported FOF-related changes in gait concerned mean values of spatio-temporal gait parameters and usually correspond to a reduced gait speed, shorter stride length, increased stride width, and prolonged double limb support time. These FOF-related changes in clinical practice are interpreted as cautious, and because no specific brain lesions may explain these changes in gait, they are classified as unspecified of high-level gait control disorders. The specific FOF-related increase in gait variability highlighted in our study confirms that FOF may be considered as a dysfunction of cortical level of gait control, as suggested in some previous studies. Indeed, stride time variability relies on central and peripheral inputs and feedback, as well as on neuropsychological function, and can be viewed as a final integrated output of the locomotor system. Thus, our result confirms that a significant increase in stride time variability related to FOF should be considered as a biomarker of impairments of higher-level gait control. The mechanisms underlying this association remain not fully elucidated, even if neuroanatomical evidence recently highlighted several cerebral networks that could explain how emotions may influence motor behaviors such as gait and posture. For instance, in terms of neuronal network, it has been shown that connections between several cortical and subcortical areas could provide an interface between emotion system and motor control system.

Meanwhile, our findings underscore mixed results, as 4 studies showed simultaneously significant and nonsignificant associations between FOF and gait variability, and 2 studies showed inconclusive results. An explanation of mixed results could be related to the various methods of FOF assessment. In the 10 studies selected in our systematic review, FOF was assessed by a single question with a dichotomous statement (yes or no); the Activities Specific Balance Confidence Scale where a higher score reflects less fear; and the FES, based on the operational definition of fear as "low-perceived self-confidence at avoiding falls during essential, relatively nonhazardous activities" where participants rate their own ability to complete a certain activity. For instance, Hausdorff et al showed that FOF evaluated by the single question was not associated with increased gait variability, whereas FES score was positively associated with increased gait variability. This result can be explained by the differences in terms of reliability between the methods used to assess FOF. We suggest that a full questionnaire would provide more consistent information on the level of FOF than a single question. This latter point has been previously suggested by Tinetti and Powell. Indeed, these authors noted that an individual with low confidence in performing certain activities tends to avoid them. Answering "no" to a single question on FOF might be explained by the fact that the person avoids all activities causing FOF. Similarly, a person might have answered "yes" to the question on FOF because she or he chose to engage in
sports or other activities that present an increased fall risk, even if she or he did not necessarily have FOF within the context of daily tasks.

On the other hand, these mixed results can be also due to the effects of potential confounders, such as slow gait velocity and history of previous falls. Reelick et al.\textsuperscript{10} showed that participants with FOF had lower gait velocity when walking at the preferred velocity with and without a cognitive dual task compared with those without FOF. In their study, they reported that stride time variability and stride length variability were associated with FOF. But, after adjustment for gait velocity, the association between gait variability and FOF was no longer significant. This result is consistent with previous findings on dual-task paradigm among healthy younger adults reporting that increased stride time variability was explained by decreased gait velocity rather than attention interference.\textsuperscript{3,39} In addition, it has been previously reported that increased gait variability is associated with the occurrence of falls.\textsuperscript{23} Moreover, history of falls and FOF were independently related to an increase in stride time variability.\textsuperscript{21} In contrast, Maki\textsuperscript{23} suggests that there is an interaction between FOF and falls, which corresponds to a synergistic effect when FOF and falls are combined. In concordance, Ayoubi et al.\textsuperscript{12} showed that a significant increase in stride time variability was related to the combination of FOF and history of falls, although FOF alone was not related to increased gait variability. This suggests that cortical gait control impairment related to FOF is more complex than expected, and may require additional disorders, such as falling, to induce significant changes in gait control.

Some limitations of this study need to be considered. First, this review included a small number of studies, which underscores that research on FOF-related changes in gait variability is still limited. Second, available data and results remain too disparate to make firm conclusions. We suggest that these divergences may be due to the effect of potential confounders, such as slow gait velocity and history of previous falls. The effects of confounders could be particularly important because most selected studies were not randomized control trials. However, it has been underscored previously that, although randomized clinical trials provide essential high-quality evidence about the benefits and harms of medical interventions, many such trials have limited relevance to clinical practice.\textsuperscript{61} Third, several diseases, and specifically those leading to gait disorders, may be associated with FOF. These diseases and FOF may increase separately and/or in combination with gait variability. Thus, it is impossible to distinguish the respective effect of FOF and these comorbidities. This problem was particularly important in our systematic review because we selected no randomized control trial. Thus, we excluded participants with comorbidities affecting gait variability, such as Parkinson disease, dementia, and rheumatologic diseases, so as to determine whether FOF should be considered as high-level impairment of gait control without any brain lesion identifiable. Fourth, there were also methodological limitations related to the nature of gait parameter used to examine gait variability. Indeed, gait variability was assessed with either SD or CoV of 2 parameters: the stride time and/or the stride length. Although it has been shown that both stride time variability and stride length variability are related to the control of the rhythmic stepping mechanism, SD and CoV may provide divergent results. Unlike SD, CoV is normalized by mean value, and is thus not directly related to anthropometric parameters, such as height or weight, which may influence the value of spatio-temporal gait parameters.\textsuperscript{18,30}

In conclusion, our systematic review and meta-analysis provides evidence that FOF is associated with a significant increase in gait variability. However, this association is of small magnitude, and other physical parameters, such as gait velocity, history of falls, and FOF-related activity restriction, should be taken into account when considering this association.

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Supplementary Data

Supplementary data related to this article can be found online at http://dx.doi.org/10.1016/j.jamda.2014.06.020.

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