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Can Dual-Task Paradigms Predict Falls Better than Single Task? – A Systematic Literature Review

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Abstract

With about one third of adults aged 65 years and older being reported worldwide to fall each year, and an even higher prevalence with advancing age, aged-related falls and the associated disabilities and mortality are a major public health concern. In this context, identification of fall risk in healthy older adults is a key component of fall prevention. Since dual-task outcomes rely on the interaction between cognition and motor control, some studies have demonstrated the role of dual-task walking performance or costs in predicting future fallers. However, based on previous reviews on the topic, (1) discriminative and (2) predictive powers of dual tasks involving gait and a concurrent task are still a matter of debate, as is (3) their superiority over single tasks in terms of fall-risk prediction. Moreover, less attention has been paid to dual tasks involving postural control and transfers (such as gait initiation and turns) as motor tasks. In the present paper, we therefore systematically reviewed recent literature over the last 7 years in order to answer the three above mentioned questions regarding the future of lab-based dual tasks (involving posture, gait initiation, gait and turning) as easily applicable tests for identifying healthy older adult fallers. Despite great heterogeneity among included studies, we emphasized, among other things, the promising added value of dual tasks including turns and other transfers, such as in the Timed Up and Go test, for prediction of falls. Further investigation of these is thus warranted.

Keywords: gait, posture, gait initiation (GI), turns, dual task (DT), attention, falls, ageing

Short running title: Predictive value of dual task on falls in healthy older adults

Introduction

Falls are the second leading cause of accidental or unintentional injury deaths worldwide, and these fatal falls are mostly prevalent in older adults. Indeed, approximately one third of individuals aged over 65 years are reported to fall each year, and even more with increasing age [14,22,73], leading to frequent injury-related hospitalizations, disability, loss of independence and increased mortality [31,86]. Fall risk and its prevention represent a major public health concern. Age-related cognitive and physical declines tend to increase risk of falling, directly through poorer motor performance and indirectly through cognitive ageing [50].

Cognitive-motor Dual Tasks and Ageing

In this context, the paradigm of dual tasks (DT) involving gait has increasingly been investigated over the last decade because of its valuable role as a clinical marker of both cognitive impairment and fall risk [66]. Indeed, dual-tasking situations, i.e. "the concurrent performance of two tasks that can be performed independently, measured separately and have distinct goals" [56], are common in daily life, especially those involving the simultaneous performance of a cognitive and a motor task. Except in the case of a low cognitive demand from the concurrent task, DT walking always leads to a dual-task cost (DTC) even in healthy young adults, that is, a decay relative to single-task performance of one or both tasks [105]. Other motor tasks such as postural tasks [17,29,74,75,84], gait initiation (GI) [25,58,59,87] or turning [23,72,88] can be used to evaluate these DTC. The physiological substrates for these motor tasks are the locomotor regions, which are widespread and thus quite commonly implicated in tasks requiring postural and motor control [91]: the temporo-parietal association cortex for production of cognitive information based on integration of signals from sensory cortex, prefrontal cortex for intention and planification, premotor cortex and supplementary motor area for motor programs, motor cortex for motor command, basal ganglia involved in both automatic and voluntary movement control, as well as the cerebellum for time regulation and feedforward control of ongoing movement, and brainstem and spinal cord for postural control and automatic process of gait. The only difference between various motor tasks would concern the degree of activation of these neural substrates, which depends on the complexity of the task (depending itself on the environment, context and individuals' capabilities). In that way, DT outcomes rely on the interplay between attention and motor control. For example, the recently described motoric cognitive risk syndrome is characterized by cognitive complaints and slow gait, and allows identification of non-demented older individuals at high risk for transitioning to dementia [1]. This demonstrates the interplay between various gait parameters and cognitive functions in elderly people and the added value of gait measurements to assess cognitive impairment.

Since the seminal article of Lundin-Olsson et al. (1997) [52] demonstrating that stopping walking when talking was a sign of fall risk in elderly, it has been proposed that an inability to produce an appropriate postural response to a DT may be due to competition for attentional resources between the postural system and the cognitive task, which increases risk of falls in older adults [104]. DT can affect motor performance differently with ageing. According to the systematic review of Al-Yahya et al. [2] and various subsequent studies [13,54,101], higher DTCs while walking have mostly been shown in healthy older adults compared to young subjects: e.g., greater decrease in gait speed, step length, step duration and concurrent task performance, and higher increase in number of steps. However, some authors found no age-related differences in terms of DTCs on gait velocity [41] or higher DT effects on average stride time in healthy young adults compared to older adults [54]. In fact, the association between age and DT interference effects may vary according to the population (frail versus non-frail older adults, age range, etc.), the type and complexity of the motor task and the cognitive concurrent task, and instruction of task prioritization [2,12,15,106]. Regarding task prioritization strategy without any specific given instruction, despite reduced abilities in reallocating cognitive resources during DT walking in healthy older adults compared to healthy young subjects, studies on DT walking initially suggested that both age groups adopt a common strategy: “posture first” [83]. Both young and older healthy adults would give priority to the stability of gait when simultaneously walking and performing a concurrent cognitive task. However, after noticing that even healthy young adults do not always prioritize gait [27,54], Yogev-Seligmann et al. (2012) [106] proposed a model of task prioritization taking into account the motor and cognitive capabilities of individuals such as postural reserve (i.e., subject’s capability to respond most effectively to a postural threat), hazard estimation (i.e., awareness of one toward himself and toward the situation and the environment), expertise (skills regarding the task), mood and personality, and nature and complexity of the secondary task.

Cognitive-motor Dual Tasks and Prediction of Falls

The role of DT paradigms in fall risk assessment is still unclear and discrepancies in the literature remain. Do DT-related changes or DT performance discriminate fallers from non-fallers? Are DT-related changes or DT performance predictors of falling? Is the DT-related predictive strength superior compared to the single-task (ST)-related one? Indeed, since 2008, seven systematic literature reviews (and four related meta-analyses) [11,24,46,60,68,103,108] have attempted to answer these questions, the last review that did not exclusively focus on walking DT having been written in 2016 [68].

From these reviews (see Table B.1 in the Supplementary Material section), we can conclude that, despite a few exceptions such as in Beauchet et al. (2008a) [9] and in Swanenburg et al. (2010) [90], most studies considered cognitive-motor dual tasks as predictors of falls in older adults. However, reviews that have attempted to determine whether DT performance or DT-related changes (changes

in performance under DT situation compared to ST condition) represent an added value for fall prediction in comparison with the corresponding single tasks either showed a negative result [60,103] or were not able to conclude [46,68,108]. On the one hand, results from reviews that did not find any superior predictive power for DT compared to ST using meta-analysis [60,103] need to be interpreted with caution. Indeed, these meta-analyses included a majority of retrospective designs for the reporting of fall history and used the mean difference as an appropriate statistical measure for discriminative ability. Thus, it is the discriminative power of DT performance (compared to that of ST) that has been assessed, more than its predictive value for fall risk. Interestingly, in Menant and colleagues' meta-analysis [60], the prediction stayed invariant when only prospective falls studies were kept. On the other hand, inconclusive reviews [46,68,108] reported some cases where DT paradigms involving gait and a mental tracking task such as backward counting [10,38,63,97] or a verbal fluency task [97] and measuring walking speed [10,97] or gait variability [38,63] were better able to predict fall risk than single tasks. The same systematic reviews [46,68,108] also presented studies reporting similar predictive power for DT and ST [6,18,28,57,82]. These studies included dual tasks with the Timed Up and Go (TUG) test, walking back and forth, quiet standing and stepping reaction responses in standing as motor tasks, and mental tracking, verbal fluency, and discrimination and decision-making tasks as the concurrent cognitive task. Therefore, in order to obtain an added value of DT performance for fall prediction over ST performance, DT walking would seem to be a better choice than dual tasks involving postural control, gait initiation or turns. Nevertheless, this cannot be firmly stated, considering the small number of consistent studies investigating such kind of primary motor tasks. Further research is needed for validating the latter observation.

Overall, discrepancies in the literature concerning the potential superior association between DT walking and prediction of falls in comparison with ST can be explained by different parameters characterizing studies: heterogeneous populations, various definitions of fall, retrospective and prospective designs, various sample sizes and follow-up periods, lack of standardization of DT methodology, and various outcome measures. Gait speed assessments, for example, showed equivalent ability in discriminating elderly fallers from non-fallers for ST and DT paradigms [60,103]. Moreover, the form of the assessed DT outcome (i.e., absolute values, relative values, thresholds) and the statistical measures for sensitivity-to-change, discrimination or predictive ability vary among articles. Finally, the type of the cognitive tasks used as well as their level of complexity could also influence the resulting predictive values and should be adapted to the studied population. For instance, Chu et al. (2013) found that, contrary to verbal fluency and manual tasks, mental tracking tasks were the only type of concurrent tasks related to a significant predictive strength for falls [24]. On the contrary, Menant et al. [60] could not differentiate ST and DT performances regarding their

predictive power for fall risk, even when comparing specific types of concurrent task, i.e. mental tracking tasks versus verbal fluency tasks. The team of Wollesen (2019) observed, for its part, an insignificant trend for increased DTC in fallers for verbal fluency and motor concurrent tasks [103]. Performance of both motor and cognitive tasks was not always reported, withholding information about strategy of task prioritization that might discriminate fallers from non-fallers in some cases. Besides, as suggested by Zijlstra et al. (2008) [108], the inconclusive results concerning the predictive power of DT for future falls in healthy older adults may be related to the existence of different fall risk factors such as muscle weakness, impaired vision and poor peripheral sensation [51] that may not all be taken into account at once through a unique DT test. Therefore, only a subgroup of fallers that have increased attention demands for motor control would be identified through a DT assessment.

Objectives

On that basis, the main objective of this review was, through a systematic review of the recent literature, to better define the role of DT in assessing the fall risk in healthy older adults, without cognitive impairment (i.e., mild cognitive impairment, dementia or neurological conditions) and/or known gait disorders. Even if DT walking conditions as well as cognitive-postural DT are mostly studied, other kinds of cognitive-motor dual tasks such as DT involving GI and turning were also explored here in order to determine if one type of DT could be more promising than another in fall risk assessment. Indeed, given that more than half of all falls of community dwellers aged 85 years and older occur at home and most often in the bedroom [65], not only straight forward walking but also standing and transfers can be associated with high fall risk in healthy older adults.

Methods

Search Strategy

This systematic review was performed in order to answer the three previously asked questions regarding cognitive-motor dual tasks involving gait, GI, posture and turning as the motor task. The most recent systematic review investigating falls and cognitive-motor DT with gait, GI, postural control but also turning as primary motor task was published in 2016 [68] and looked at articles with dates of publication up to September 2013. For this reason, we chose to systematically add articles that were published between January 2013 and June 2020 while studying the questions stated above.

In this context, we used PubMed, Cochrane CENTRAL, Scopus, Web of Science and Google Scholar as electronic databases. We did not have access to EMBASE but the use of Cochrane CENTRAL and Scopus that partly include records from EMBASE was an appropriate alternative. The search strategy was based on the PICO (Population Intervention Comparison Outcome) framework in order to formulate a well-structured question related to the problematic of interest [61]; i.e., Population: healthy older

adults, Intervention: cognitive-motor DT, Comparison: single tasks, Outcome: fall-risk prediction. In this line, the search terms were adapted to the assessed motor task and the chosen database. These keywords are summarized in the Table A.1 in the Supplementary Material section.

Inclusion and Exclusion Criteria

Inclusion criteria for the selection of an article were related to different domains: (1) the objective: relative to the potential predictive power of DT regarding fall risk or to their ability to discriminate between fallers and non-fallers, with or without a comparison with the predictive strength of ST; (2) the studied population: relatively healthy older adults (60 years-old and older or with a mean age of at least 65) without cognitive or gait impairment caused, for example, by neurodegenerative diseases and therefore, without any use of an assistive device for walking (e.g., cane or walker); (3) the assessment tool: detailed DT combining gait, GI, posture or turning with a concurrent cognitive task (a secondary motor task being also accepted) and performed in a lab environment; (4) the study design: prospective and retrospective recording of falls; and (5) the language: paper written in English. Concerning exclusion criteria for selection, articles that aimed to assess the ability of DT to prevent falls as well as interventional studies were rejected. Furthermore, review papers or studies with a secondary analysis of previously reported results or being already part of systematic reviews published prior to 2013 were not included in the systematic literature review.

Quality Assessment

The risk of bias was assessed for each selected article by the Quality in Prognostic factor Studies (QUIPS) [36,37]. This tool is based on six risk of bias domains: study participation, study attrition, prognostic factor measurement, outcome measurement, study confounding (adjustment for other prognostic factors), and statistical analysis and reporting. From two to four domains with moderate bias or from one to two domains with high bias, we considered the quality of the study to be moderate. A high-quality study was associated with less bias, whereas more bias led to classify the paper as an article of poor quality. Two reviewers (MB and LD) independently performed this quality assessment, with any potential discrepancy resolved thanks to a third independent reviewer (AD).

Data Extraction

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses; [64]) guidelines were followed in order to clearly report the results of our systematic review. Among others, the PRISMA flow diagram was used (see Figure 1) in order to illustrate the process of manuscripts selection. After having performed searches within the selected databases by using the search strategy previously described, duplicates were removed. Subsequently, two independent reviewers (MB and LD) screened articles via their title and abstract and selected them based on the inclusion and exclusion criteria.

Afterwards, other papers were excluded after full-text check if considered to be irrelevant regarding our criteria or with high risk of bias. Again, in case of any disagreement regarding articles selection, a third independent reviewer (AD) was asked to help for solving it. Once all the articles were selected, we extracted a range of information from each paper: authors, year of publication, study design, sample size, sample demographics (gender distribution, mean age, residential setting, cognitive screening, inclusion and exclusion criteria), method of fall ascertainment, fall outcome measure, fall definition, months of follow-up, proportion of fallers, DT test (motor and cognitive tasks descriptions, with details on how the test result variables were used in the analysis; same as for the ST test), instructions of prioritization, statistical results from the study regarding discriminative and/or predictive power of DT (over ST), answers to the three questions asked in this systematic review, risk of bias related to the article (QUIPS score), and limitations of the study. Cognitive tasks involved in DT test were classified according to the system developed in [8] and adapted from [2]. This classification was also used for detailing the previous systematic review on the topic (see Table B.1 in the Supplementary Material section).

Results

Thirty studies were selected according to selection criteria (Figure 1). As expected, a greater number of articles related to walking DT (sixteen studies; see Table 1 or more detailed Table C.1 in the Supplementary Material section) were found in comparison with the other sorts of cognitive-motor DT involving GI (one paper; see Table 2 or more detailed Table D.1 in the Supplementary Material section), postural control (seven papers; see Table 3 or more detailed Table E.1 in the Supplementary Material section) and turns (six papers; see Table 4 or more detailed Table F.1 in the Supplementary Material section).

Dual-task Walking

In the context of DT involving gait, three selected manuscripts [32,44,45] also referred respectively to outcomes from a previous study from the same research group on the same amount of subjects from the same dataset, but with other research questions and methodologies [33,42,43]. Only the recent studies were thus included, at the expense of the previous ones, but all the results were considered. Among the sixteen selected papers that included cohorts from 27 to 1350 older adults (with a mean age exceeding 65 years and a healthy cognitive status), nine were retrospective, whereas the others had a prospective design. Information regarding fall occurrences was collected thanks to questionnaires, interviews, postal surveys, calendars, phone calls or diaries. Regarding the walking task being part of the DT condition, subjects were mainly asked to walk straight forward on the ground at self-selected comfortable speed, and sometimes on a narrow path [34], avoiding obstacles or reaching

targets [19]. According to our classification of concurrent cognitive tasks ([8], adapted from a previous one proposed by Al-Yahya and colleagues [2]), eleven studies investigated walking DT involving mental tracking/working memory tasks [7,19,21,26,32,34,35,53,62,98], while one [40] and four [30,44,45,69] papers respectively studied a discrimination and decision-making task and verbal fluency tasks as cognitive tasks. One study compared two concurrent tasks: a verbal fluency task and a motor task [30]. Finally, in terms of strategies of task prioritization between both simultaneously performed tasks, instructions were either not given or indicated equal prioritization. Most DT walking studies (eleven out of twelve) agreed on the power of DT walking in discriminating between fallers and non-fallers (i.e., presenting DT-related parameters that significantly differ between both groups), except in a single study from this systematic review [30]. Moreover, the predictive power of DT walking for future falls was also confirmed in most papers included in the present review (eleven out of twelve), with few exceptions such as in Gimmon et al.'s manuscript [34]. However, as in previous reviews, we obtained inconclusive results concerning the superiority or added value of DT over ST tests in terms of fall prediction in healthy older adults. Indeed, based on the ten recent studies that attempted to answer this particular question, only five of them [7,32,35,47,98] showed the superior predictive strength of DT over ST, two articles observed the same predictive value of both ST and DT [19,45], and three studies demonstrated the superiority of ST over DT in terms of fall risk prediction [21,34,44].

Dual Tasks Involving Gait Initiation

When searching for studies assessing gait initiation (GI) DT, only one prospective study [20] was found to instruct participants to perform a real DT test according to the definition from McIsaac et al. (2015) [56]. Falls were reported via postal surveys, a falls calendar, as well as phone calls. One hundred and twenty-four cognitively healthy participants, with a minimum mean age of 70 years in each group, were assessed. As motor task, subjects were asked to start walking straight forward in response to a buzzer activated at random times, whereas the concurrent cognitive task was a mental tracking/working memory task. Instructions of prioritization were not given or at least, not reported. DT involving GI seem to be useful tools for identifying future fallers. As conclusions, Callisaya et al. [20] showed that their DT paradigm involving GI was a good predictor of future falls, but no improvement of the prediction value compared to the ST alone was observed.

Postural Dual Tasks

Among the papers that have investigated the predictive power of postural DT for risk of falls, one of them [76] also related the results from a previous study led by the same research group on the same data [77]. The cohort used in Zhou et al. (2017) [107] was based on the population analyzed in Kang et al. (2013) [48], but with additional subjects, for which reason we considered these two articles

separately. Five studies were designed as retrospective studies [55,76,79,96,102], whereas the two others were prospective [48,107], with information about falls provided through interviews, falls calendar or phone calls. The populations involved ranged from 23 to 738 cognitively healthy older adults, aged on average from 69 to 81 years. Regarding the postural task, quiet standing with eyes open was performed in all the selected studies, except for that led by Westlake and colleagues [102], where postural stability had to be maintained under predictable and unpredictable perturbations. Moreover, the postural DT condition was compared with a walking DT condition in the works of Rinaldi et al. [77] and Santos et al. [79]. In terms of concurrent tasks, four studies used a mental tracking/working memory task (backward counting and 1-back verb generation task) [48,55,102,107], but a verbal fluency task [102], a discrimination and decision-making task [96], and a grasping task [76,79] were also carried out. While participants were clearly instructed to prioritize balance over the concurrent task in the context of two studies [48,96], either no instructions of prioritization were given or no instructions were reported in the others. In terms of outcomes, recent literature concerning postural DT seems to confirm the fall-risk discriminative (six studies out of six [55,76,79,96,102,107]) and predictive (two papers out of two [48,107]) power of such tasks in healthy old people (see Table 3). However, their superiority over single tasks is still a matter of debate (demonstrated by one manuscript [107] out of two prospective studies).

Dual Tasks Involving Turns

Finally, there were 6 papers studying DT that involve turns as the motor task: from 36 to 649 older adults participated and the maximum mean age was 82 years. Four [3,4,71,93] and two [5,67] papers presented results from studies with respectively a retrospective design and a prospective design. Falls were described via self-administrated questionnaires, interviews, phone calls or diaries. All the studies asked to perform a Timed Up and Go test (TUG test, a test that includes walking, turning and transfers) or a walking task with turns [67]. The latter study used different DT paradigms with straight walking with or without obstacles, walking with turns, stair descent or TUG test as primary motor task. The concurrent task was a motor task in three papers [3,67,71], a mental tracking/working memory task in five manuscripts [3,5,67,71,93], and a verbal fluency task in one study [67]. No instruction for prioritizing one task over the other was found in any of the articles. In terms of the questions asked in the context of the present systematic review, five papers out of a total of five respectively agreed on the fall-risk discriminative [3–5,71,93] and predictive [4,5,67,71,93] power of DT involving turns. Besides, among five articles that compared DT and ST in terms of fall prediction, four concluded in favor of the DT condition [4,5,71,93] and the last one was inconclusive [67].

Discussion

Dual-task Walking

When considering recent literature over the last 7 years, only one study [30] out of twelve did not agree on the power of DT walking in discriminating between fallers and non-fallers. Various explanations can be proposed regarding this controversial result: healthy older adults that only fell once were studied; a relatively easy verbal fluency task (naming animals without repeating names) and motor task (transferring a coin from one pocket to the other) were used as concurrent tasks; and fallers might have prioritized the walking task over the concurrent task, unknown information since the concurrent tasks were not assessed separately.

Moreover, a paper written by Gimmon and colleagues [34] was the sole recent study (out of twelve selected studies) that did not confirm the predictive power of DT walking for future falls in healthy older adults. This latter study investigated a DT involving a narrow path walking test simultaneously performed with three different mental tracking/working memory tasks. While trial velocity during both ST and DT conditions similarly remained significantly slower in fallers compared to non-fallers after adjustment for covariates (with no added value of DT over ST condition in identification of fallers), significant predictive abilities (in terms of area under the curve or AUC) were found for ST trial velocity, but not for DT trial velocity. This might be due to the difficulty of the walking task alone that could already be interpreted as a DT. By consequence, a ceiling effect might have been observed under the DT situation that could be rather considered as a triple task.

However, inconclusive results were obtained concerning the superiority or added value of DT over ST tests for predicting future falls in a population of healthy older adults. All the studies that demonstrated the superior predictive strength of DT over ST presented a prospective design (except the paper from Halliday et al. [35]), allowing to induce causal inferences. They also all investigated DT conditions with a mental tracking/working memory task as a concurrent task. The DT-related gait parameters that seemed to be good predictors of future falls were: poorer performance in the PCA-derived DT pace domain (including velocity and step length) [7], increased variability (coefficient of variation; CoV) [47] for step width, step length [35,47], step time, stance time, stride time, stride velocity and swing time [35,47], and symmetry DTC [32]. Moreover, Verghese et al. (2017) did not observe any change in gait pattern under DT conditions, but higher prefrontal activation levels on fNIRS during DT walking [98]. In a second study [32], Gillain and colleagues used a supervised machine learning algorithm (J48 classifier) in order to build a classification tree for identifying future fallers. The obtained model included: symmetry DTC, stride length in fast walking ST, stiffness, mean MTC (minimum toe clearance) in normal speed walking ST, MTC CoV DTC, MTC variance and mean MTC in

fast walking ST, difference between maximum and mean MTC in DT and gender. Although the sample size was small, with more non-fallers than fallers, and no external validation was performed in another independent sample, this classification tree showed good performance, with an accuracy of 84%, a sensitivity of 80%, a specificity of 87% and an area under the ROC (receiver operating characteristic) curve of 0.84.

On the contrary, articles that either observed the same predictive value of both ST and DT [19,45] or the superiority of ST over DT in terms of fall risk prediction [21,34,44] were all designed as retrospective studies, except for the study of Howcroft and colleagues (2018) [45]. These conclusions have thus to be taken more cautiously in view of possible inaccurate recall of falls and changes to gait patterns between falls and gait assessment either due to fear of falling or in order to increase stability after a fall. Indeed, Howcroft et al. (2018) [45] have demonstrated, on quite similar data collections, that the study design has an impact on gait differences between fallers and non-fallers. The studies that did not observe a significant added value of the use of DT over ST tests for prediction of fall risk involved a mental tracking/working memory task [19,21,34] or a verbal fluency task [44,45] as a concurrent cognitive task. Some gait parameters that were shown to be better predictors of future fallers under the ST condition compared to the DT situation were: slower ST trial velocity versus slower DT trial velocity (assessed via ROC curves and related parameters) [34], and longer time for ascending stairs compared to slower DT walking speed (evaluated by a multivariable logistic regression model) [21]. Furthermore, ST sensor-based gait assessment models (including 30 pressure insole parameters and 29 accelerometers parameters at different body locations) were demonstrated to outperform models based on DT walking (on the basis of supervised machine learning models such as multi-layer perceptron neutral network, naïve Bayesian, and support vector machine) [44]. Afterwards, the same research group (Howcroft and colleagues) did not find any difference in terms of predictive strength between normal walking and DT gait, when similarly analyzing prospective data [45]. In this way, through a binary logistic regression analysis and investigation of ROC curves, Caetano et al. did not allocate greater predictive power of fall risk to gait adaptability test (walking with/without obstacles and/or targets) performed under DT condition compared to ST gait adaptability test. This might be due to the fact that the ST test can be understood as a DT situation and thus, ST velocity would already be a sufficient predictor of fall risk.

The above results should be cautiously interpreted because of discrepancies across studies regarding population, study design, DT paradigm, measurements and statistical analyses. In this regard, interesting findings have been reported. Firstly, DT decrements seem to be greater in women than in men, inducing a greater risk of falls in females and explaining therefore their higher fracture risk [47]. Secondly, the use of a cognitive concurrent task seems more appropriate than a manual task for

predicting falls in older adults walking. Indeed, although Freire et al. (2017) [30] did not manage to discriminate fallers from non-fallers under DT situations, they showed a significant larger reduction (DTC) in step length in older adults during the cognitive-motor DT condition in comparison with the motor-motor DT condition, as well as a greater DTC (i.e., DT-related increase) in stride time variability in non-fallers performing the cognitive task instead of the manual task while walking. Muhaidat and colleagues, for their part, found the best predictive values for walking while avoiding a moving obstacle as well as for a triple-task test that consists in straight walking while performing a visuospatial clock task and carrying a cup [67].

Dual Tasks Involving Gait Initiation

With regard to the unique recent paper on the topic [20], DT involving gait initiation (GI) seem to be useful tools for identifying future fallers. The prospective design of this study added even more reliability to DT-related prediction power. The statistical test for assessing the predictive strength of DT condition was log multinomial regression analysis. Slower first step execution time under both ST and DT conditions, slower swing time during DT and slower time to first lateral movement under ST were significantly associated with higher risk of multiple falls, while parameters of GI were not found to be predictors of single falls. However, Callisaya et al. [20], with their DT comprising GI in response to a buzzer activated at random times and a mental tracking task (3-serial subtraction), did not observe any improvement of the prediction value compared to the ST alone. Indeed, slower time to first lateral movement under ST showed the strongest association with multiple falls. Once again, a potential explanation of such a result could be the fact that the ST condition can already been considered as a DT situation: stepping forward as soon as the buzzer sounds (i.e., reaction time task), while maintaining balance and preparing for sufficient motor performances (as perceived in [92]). Therefore, due to the high level of difficulty of the DT test, two consequent behaviors may potentially be observed: older adults globally exhibited poorer features of the first step (longer step execution time and time to first lateral movement) than under ST, and some non-fallers may therefore be less separable from fallers on the basis of such parameters; or multiple fallers may choose a “posture first” strategy under the DT (i.e., more attention allocated to the GI task compared to the concurrent cognitive task) because of their lack of cognitive resources to manage two tasks at the same time. In this line, performance related to the concurrent cognitive task alone should be assessed in [20] and, more generally, in DT studies. In any case, more investigations need to be carried out in order to clearly and reliably answer to the question of the additional value of GI DT for fall prediction. In fact, too few papers were interested in GI under DT condition for predicting falls and the previously written (discriminative) papers did not show outcomes in accordance with the ones obtained by Callisaya and colleagues. St George et al. (2007) investigated a choice stepping reaction time (CSRT) test coupled with a

visuospatial working memory task and found a significantly greater increase in step response time under DT compared to ST in healthy older adult fallers versus non-fallers, as well as a higher amount of secondary task errors in fallers [89]. Uemura and colleagues (2012) [95], for their part, studied the completion of a DT test composed of a GI task as soon as a LED was switched on, and a backward counting task (i.e., mental tracking task). Despite the suspected cognitive impairment of the population in view of their RDST score, the authors observed a lower backward displacement and velocity of the COP in DT condition in fallers compared to non-fallers, and not under ST conditions.

Other recent papers found during the present systematic search, that assessed challenged step or gait initiation in healthy older adults [80,81,94], were also able to predict future falls. Nevertheless, they were not retained in this systematic review because the tasks used (e.g., "ordered multi-stepping over hoop"(OMO) test, CSRT test, inhibitory CSRT/iCSRT test, and Stroop stepping test/STT) were not clearly considered as DT (according to the definition proposed by [56]), but rather as two successive ST. Indeed, such kind of tasks consisted of a reaction time task, discrimination and decision-making task or mental tracking/working memory task waiting for the initiation of a step as response. Slower OMO performance [94] and increased amount of SST errors [81] were significant predictors of fall risk. Furthermore, iCSRT was demonstrated to better identify future fallers than SST and CSRT test: decreased RT remained significantly associated with falls, independently of balance, attention or processing speed [80]. On the other side, as explained above, these tasks can also be seen as cognitive-motor DT that require to simultaneously maintain stability and perform a cognitive task with a motor response. In any case, these high-load tasks involving GI need to be further investigated, by comparing their prediction power with their DT equivalent and by exploring additional parameters directly related to the motor task such as spatial and temporal features of APAs (as done in [92]).

The interest of studying GI more thoroughly under DT condition (or challenged step initiation) in the future can be supported, for instance, by findings from [95]: neither a ST steady-state walking nor a DT condition involving steady-state walking and a mental tracking task would be a predictor of falls in older adults, whereas a DT comprising GI and the same concomitant task performed on the same population would present an added value for fall-risk prediction over ST. Because tests such as OMO, CSRT, iCSRT tests and STT ask to perform steps in multiple directions, it should also be explored whether the combination between GI and turns is not even better for predicting future fallers.

Postural Dual Tasks

When the fall-risk discriminative and predictive powers of postural DT were mostly proven (in respectively six studies out of six and two studies out of two, in the present review), the additional value of such tasks compared to single tasks is still uncertain. Here again, the choice of the postural

outcomes to assess seem to be crucial. Indeed, a possible reason why Kang et al. [48] did not manage to show the added value of DT on a reduced but similar data collection compared to the one used in Zhou and colleagues' investigations [107] is probably the different postural parameters measured in both studies. The concurrent cognitive task consisted in a usual backward counting task, with an individual adaptation of the task in case of difficulty, and a negative binomial regression analysis was carried out in these manuscripts. Lower DT postural sway complexity (calculated by using multiscale entropy) was shown to be a better predictor of future fall risk than ST postural sway complexity in [107]. On the contrary, independently of the condition (ST versus DT) , greater postural stiffness and damping were significantly associated with lower outdoor fall risks, while greater COM root mean square (RMS) and damping in the AP direction were respectively associated with higher and lower rates of indoor falls [48].

In view of the small number of papers comparing the fall-risk prediction power between postural ST and DT conditions, DT-related features that allowed to discriminate between fallers and non-fallers in retrospective studies may be a useful starting point. For example, in a DT with postural perturbations and a verbal fluency or a mental tracking/working memory task as concomitant task, fallers exhibited a higher amount of grasp errors (i.e., failing to grab a handrail in order to maintain postural stability) under both DT conditions in comparison with older adult non-fallers [102]. Besides, a DT task that combined a quiet stance on a firm surface with a backward counting task [55] allowed discrimination between frequent fallers (with more than two falls) and non-fallers (via the maximum distance between two points of the AP time series and the average COP in the AP and ML directions), and between infrequent and frequent fallers (through the maximum distance between two points of the AP time series). Nevertheless, performing a postural ST with eyes open on a compliant surface and using the parameter derived from the first principal component coming from a PCA on posturographic parameters were the only conditions for discriminate infrequent and frequent fallers from non-fallers, and between both groups of fallers. The first principal component included posturographic parameters concerning the AP variation in COP displacement: average AP distance from the mean COP, AP RMS distance and maximum distance between two points of the AP time series. Moreover, in a study comparing a quiet standing ST and DT with a simultaneous tone-counting task [96], fallers had a significantly greater area of sway, AP and ML standard deviation of COP displacement compared to non-fallers, but without any significant interaction between task condition and group. This might be due to the fact that quiet standing is a relatively easy task. Finally, when analyzing a concurrent motor task that consisted in grasping a dowel with different levels of difficulty while staying stationary or while walking [76,79], a generalized slowing down in movement performance (including upper limbs movements) was observed in fallers [77], as well as a greater decoupling between walking and

prehension [76]. In another study that investigated walking or postural control during a manual task (grasping, transporting and placing a dowel as close as possible to the center of a target) [79], fallers and non-fallers were significantly different only in terms of manual task performance. Regarding the dowel-positioning task, fallers were less accurate particularly during the walking DT combined with an 8-cm target, and slower especially during the postural DT and for a target located at a long distance.

From all these studies of postural DT, interesting methodological observations can be made. Dual task-related discriminant parameters did not differ when using a verbal fluency task or a mental tracking/working memory task as concurrent cognitive task [102]. We have also learnt that a concomitant manual task was useful to discriminate between fallers and non-fallers [76,77,79], through different DT-related changes in manual task according to the primary motor task (gait versus quiet stance in [77] and [79]). A study that was excluded due to the lack of information and criteria regarding global cognitive functions of the studied population [78] compared two postural DT conditions involving respectively a mental tracking/working memory task and a manual task as a concomitant task. As results, using a manual concurrent task with traditional analyses of postural control (larger AP and ML sway range and 95% confidence ellipse area) or using a concomitant cognitive task with non-linear analyses of balance control (larger ML α-scaling exponent and smaller ML sample entropy) were efficient ways to discriminate fallers from non-fallers. Whereas Maranesi et al. (2016) [55] failed to differentiate infrequent from frequent fallers by means of a postural DT involving a backward counting task, other types of DT should be examined.

Dual Tasks Involving Turns

Regarding DT involving turns, most of the recent studies found in the context of the present systematic search agreed on the fall-risk discriminative and predictive powers of such task (in five papers out of five for both aspects), as well as on their added value in terms of fall prediction over the associated ST (in four selected articles out of five). Particularly, better predictive properties were allocated to the frequency-based and distance-based features (the fusion of the distance-based features being the best predictors of fall risk) compared to the traditional parameters, and especially for the cognitive DT version of TUG test (combination with a mental tracking/working memory task) in comparison with ST and manual-TUG DT [71]. Moreover, in the context of a DT involving the TUG and a serial-1 subtraction task, both TUG-ST score and DTC value (proportionate difference, with the mean completion time among ST and DT as divisor) were significantly associated with falls history, in particular in a transitional functioning group but not in a well-functioning group [4]. Either the tasks or the measured parameters were thus not sufficient to identify any kind of fallers. Tomas-Carus et al. [93] studied exactly the same type of DT, but focused on fall predictors according to gender. In men, a significant AUC for predicting risk of falls was found for mean TUG-DT time, the sum of the mean TUG-DT time and the mean number

of cognitive stops, the sum of the mean TUG-DT time, the mean number of cognitive stops and the mean amount of cognitive errors, and the DTC value (difference in time spent between TUG-ST and TUG-DT, divided by the average score between both tasks), which was shown to be the best predictor. In women, on the contrary, the best predictor for future falls was the sum of the mean TUG-DT time, the mean number of cognitive stops (i.e., stopping while walking for performing the concurrent cognitive task) and the mean amount of cognitive errors, whereas the sum of the mean TUG-DT time and the mean number of cognitive stops was also able to identify elderly women at high risk of falls. Still regarding the same cognitive-TUG DT, Asai et al. (2020) [5] performed the only conclusive prospective study and demonstrated that DT may provide an additional value in TUG for predicting falls among old-older adults, with a longer TUG-ST time and a lower DTC value that were significantly associated with falls occurrence. However, it was not the case among young-older adults. Finally, a last study from Muhaidat and colleagues [67] presented inconclusive outcomes. In fact, based on univariate binary logistic regression analyses, several variables related to ST and DT conditions were found to be significantly associated with fall risk: time for avoiding a moving obstacle in ST and DT while carrying a cup, time required to perform the walking task in a triple-task test, time for TUG in DT involving a concurrent manual task, and absolute difference for TUG time between ST and DT. Nevertheless, a multivariate analysis with these parameters failed to identify a useful predictive tool.

In the future, it will be necessary to carry out more prospective studies regarding DT with the TUG test and a cognitive task, while specifically analyzing the turning phase of this task. Indeed, the predictive power of a cognitive-motor DT involving gait, turn and transfers has been proven but the DT situations with turning as the only motor task have not yet been investigated. It is also interesting to note that absolute differences of performance between ST and DT TUG seem to be better predictors of falls in older adults than proportionate differences [67]. Next, concerning the nature of the concomitant task, while Ponti et al. [71] emphasized the fall prediction power of a concurrent mental tracking/working memory task over a manual task, Ansai et al. (2016) did not show differences in discriminative power of both TUG tests with a cognitive or a motor concurrent task in terms of fall status [3]. Unselected studies due to a poorly described population have provided supplementary information [85,100]. In line with [3], Smith and colleagues [85] observed a more disturbed overall performance in older adults during TUG-DT with a mental tracking/memory working task compare to a manual task, but no significant interaction between group and task condition was found. Finally, a verbal fluency task combined with a TUG test did not allow fall prediction, when using standard completion time as tested independent variable [100].

Limitations

This systematic review presented some limitations that may have impacted on our conclusions. Firstly, the studied population was restricted to healthy older adults (without cognitive or motor impairments), limiting therefore the generalization of our results. However, two reasons justified the choice of studying this particular group. On the one hand, studying the strength of dual tasks in predicting falls in a limited population makes sense when we assume that particular group characteristics (e.g., neurodegenerative diseases) may influence DT testing parameters in a unique manner compared to other groups. On the other hand, while older individuals living with assistance, in institutions or suffering from diseases such as mild cognitive impairment, Alzheimer's disease, Parkinson's disease (PD) or stroke are already considered at high risk of falling, the ability to discriminate fallers from non-fallers in a population of healthy community-dwelling older adults is of high interest. Secondly, another limitation of the present review was the selection of studies assessing DT only in a lab environment. Indeed, these conditions do not reflect the reality, but one of our objectives was to inform health workers about the most promising kind of DT for assessing fall risk in health structures. Nevertheless, indoor, ecologically valid approaches still need to be investigated.

Conclusion

Recent literature confirms the discriminative and predictive values of a cognitive-motor DT for fall risk in healthy older adults but does not allow definitive conclusions to be drawn regarding the potential added value of DT over ST. Indeed, the global motor capacity of the subject also seem highly predictive of falls and has even been proposed as a marker of cognitive decline in older adults [99]. Overall, cognitive-motor DT involving GI or postural control for the motor task have not been enough tested for their fall prediction power in the literature. On the contrary, cognitive-walking DT tests are widespread, but a lot of different DT paradigms were investigated, leading therefore to only half of the studies that proved the superiority of DT over ST in terms of prediction of future falls. Dual tasks with turns (mostly involving walking and transfers with a turn through the TUG test) represent quite useful tools thanks to consistent results about their additional value over ST for the identification of future healthy older adult fallers.

Future prospective studies (with a homogenous definition of falls and a substantial follow-up period) should assess DT and corresponding ST in sufficiently large and heterogeneous elderly populations, while investigating different motor tasks (i.e., gait, step initiation, standing and turning, with various stages of complexity) and cognitive tasks (i.e., one task of each category [8], with different levels of difficulty). Preference should be given to mental tracking/working memory tasks (e.g., backward counting) because of their easy implementation and their proven superiority compared to other

concurrent cognitive and motor tasks involved in any kind of cognitive-motor DT in previous reviews and recent literature. Dual-task paradigms, tools of assessment, further calculations of parameters of interest and statistical tests have to be clearly and fully reported for further potential replications. Including confounders such as gender, age, cognitive abilities, physical performance, mobility assessments and concern about falling within regression models or models of classification is necessary. The performance of both the cognitive and motor tasks under DT and ST conditions must be reported in order to understand which strategies of prioritization have been used by the participants. It is also important not to instruct any task prioritization to subjects (and not to forget to mention these given instructions) and to randomize the order between ST and DT among participants. A special concern should also be given to the identification of infrequent fallers, and not only frequent fallers.

Because fall risk is dependent on different factors in addition to deficits in physical and cognitive functions [16], the most relevant cognitive-motor DT for fall prediction in healthy older adults that will have been found by following the above listed recommendations will then have to be compared with other fall-risk assessment tools and probably integrated within a multimodal clinical assessment.

Continuing investigations of cognitive-motor DT for fall-risk prediction is encouraging by the fact that daily-living walking bouts have been recently shown to be more similar to in-lab DT walking in comparison with ST gait [39]. Along with the usual behavioral assessments of motor and cognitive tasks under ST and DT conditions, measuring neural activity during DT [98], during a computerized cognitive task [35] or through transcranial magnetic stimulation [69] can provide additional information concerning a risk of falls. When light will be shed on this concern of falls prediction in healthy older adults, it will be interesting to extend the research through other specific populations such as older adults with cognitive impairment or neurological diseases. For example, Plotnik and colleagues (2011) have demonstrated the superior fall-risk predictive power of DT walking over ST in adults with PD [70].

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Disclosure of interest

The authors declare that they have no competing interest.

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Figure legends

Figure 1 PRISMA flow diagram that summarizes the process of manuscript selection.

Tables

Table 1 Articles regarding walking dual tasks that were included in the systematic literature review. Abbreviations: y. = years; F = females; M = males; # = number; GDS = Geriatric Depression Scale; MMSE = Minimal Mental State Examination; AP = anteroposterior; ML = mediolateral; CoV = coefficient of variation; PFC = prefrontal cortex; RBANS = Repeatable Battery for the Assessment of Neuropsychological Status; EF = executive function; REOH = ratio of even to odd harmonics; MLE = maximum Lyapunov exponent.

Authors	Population	Falls	Dual-task paradigm	(1) Do DT-related changes or DT performance discriminate fallers from non-fallers? (2) Are DT-related changes or DT performance predictors of falling? (3) Is the DT-related predictive strength superior compared to the ST-related one? (Yes/No/Inconclusive/Not addressed)	Risk of bias via QUIPS tool
Ayers et al., 2014 [7]	646 community-dwelling older adults: 337 fallers (80.5 ± 5.4 y.; 219 F; Blessed score: 1.7 ± 1.5) and 309 non-fallers (79.2 ± 5.5 y.; 176 F; Blessed Score: 1.7 ± 1.6)	**Prospective** study; Mean follow-up of 2.6 years; →Fallers = (# of falls ≥ 1) during the follow-up period	Motor task: **walking** 4.6 m at normal pace Concurrent cognitive task: **mental tracking/working memory task:** reciting alternate letters of the alphabet	**(1) Not addressed, (2) Yes & (3) Yes:** **Shorter step length in DT condition predicted falls**. **Poorer performance in the DT "pace" domain (including DT velocity and step length)** remained a significant predictor of falls. → **Incremental validity of DT over ST walking assessment in the prediction of falls**.	Low risk of bias
Hirashima et al., 2015 [40]	92 volunteers from a community senior club: 16 fallers (78.1 ± 5.6 y.; 13 F; MMSE: 28.1 ± 1.6) and 76 non-fallers (74.9 ± 5.3 y.; 65 F; MMSE: 28.1 ± 1.7)	**Prospective** cohort study; Over a follow-up period of 12 months; → Fallers = (injured because of falls or # of falls ≥ 2)	Motor task: **walking** 60 m (10 m walkway with 3 returns) at usual speed Concurrent cognitive task: **discrimination and decision-making task**: not stepping on the unequal lines	**(1) Yes, (2) Yes & (3) Not addressed:** Fallers and non-fallers significantly **differed in terms of the presence of missteps at 40 m and 60 m**. Subjects who had made **missteps during the DT test with an extended walking distance of ≥ 40 m** were significantly more likely to be fallers.	Low risk of bias
MacAulay et al., 2015 [53]	416 relatively healthy and cognitively intact older adults, 67.5% female: 81 fallers (69.6 ± 6.81 y.; initial MMSE: 29.47 ± 0.87) and 312 non-fallers (70.13 ± 6.62 y.; initial MMSE: 29.25 ± 1.02)	Longitudinal (**prospective**) study; Structured clinical interview after 1 year in order to obtain participant's fall history for the past year; → Fallers = (# of falls ≥ 1)	Motor task: straight **walking** at normal everyday walking speed Concurrent cognitive task: **mental tracking/working memory task**: spelling a word of 5 letters in length backwards aloud	**(1) Yes, (2) Not addressed & (3) Not addressed:** At baseline as well as at follow-up, fallers exhibited **shorter stride length** than non-fallers within both walking task conditions (**ST and DT**). There was **no significant interaction between group and task conditions on gait stride length**. Shorter strides during DT at follow-up were predicted by worse executive attention/processing speed performance 1 year before.	Low risk of bias
Gimmon et al., 2016 [34]	160 older adults: 61 fallers (79.4 ± 5.7 y.; 49 F; MMSE: 28.19 ± 1.53) and 99 non-	Participants were asked to **retrospectively** recall fall	Motor task:	**(1) Yes, (2) No & (3) No:** **Trial velocity during ST** remained significantly **slower** in fallers compared to non-fallers.	Low risk of bias

	fallers (81.5 ± 5 y.; 69 F; MMSE: 27.9 ± 1.65)	events during the past year; → Fallers = (# of falls ≥ 1)	narrow path **walking** test = walking at a comfortable pace within a 6 m long narrow path Concurrent cognitive tasks: 3 **mental tracking/working memory tasks**: reciting the days of the week backwards, reciting the months of the year backwards, serial-5 subtraction loudly from 100 to 50	There was no significant interaction between group and task. → **No added value of DT condition over ST condition in identification of fallers.** **Significant predictive abilities of ST trial velocity and not for DT trial velocity.**	
Howcroft et al., 2016 [43,44]	100 community-dwelling older adults: 24 fallers (76.3 ± 7 y.; 11 F) and 76 non-fallers (75.5 ± 6.6; 45 F)	**Retrospective** study; Classification based on 6-month retrospective fall occurrences; → Fallers = (# of falls ≥ 1)	Motor task: **walking** 7.62 m Concurrent cognitive task: **verbal fluency task**: saying words starting with A, F or S	**(1) Yes, (2) Yes & (3) No:** Fallers showed significantly **greater head posterior standard deviation decreased posterior pelvis AP REOH during ST**, and **greater posterior pelvis vertical MLE during DT gait**. In the context of models of wearable-sensor based fall-risk classification in older adults, **ST sensor-based gait assessment models outperformed models based on DT walking** or clinical assessment data.	Moderate risk of bias
Johansson et al., 2016 [47]	1390 fairly healthy community-dwelling older adults aged 70 years (684 F; MMSE: F → 28.5 ± 1.6 vs. M → 28.3 ± 1.7): over 1350 → 148 fallers (88 F)	**Prospective** study; Self-reported fall data by telephone 6 and 12 months after examination; → Fallers = (# of falls ≥ 1)	Motor task: **walking** 8.6 m at preferred pace (+ walking at fast speed only under ST condition) Concurrent cognitive task: **mental tracking/working memory task:** counting backward from 100 in increments of 1	**(1) Yes, (2) Yes & (3) Yes:** Significantly **greater step width, step length, step time and stance time variability** in fallers **during the fast-speed trial.** Nevertheless, **during DT**, fallers exhibited significantly **increased variability for step width, step length, stride length, step time, stance time, stride time, stride velocity and swing time** in comparison with non-fallers. Moreover, **step width variance from the DT trial** represented an **independent predictor** of incident falls, **as well as other gait parameters under DT**.	Low risk of bias
Pelosin et al., 2016 [69]	31 older adults: 17 fallers (73.4 ± 4.2 y., 10 F, MoCA score: 26.4 ± 1.6) and 14 age-matched non-fallers (72.1 ± 4.9 y., 5 F, MoCA: 28.3 ± 2)	Cross-sectional (**retrospective**) study; Self-reported falls over the previous 6 months; → Fallers = (# of falls ≥ 2)	Motor task: **walking** in a corridor at a comfortable speed for 1 min Concurrent cognitive task: **verbal fluency task**: talking	**(1) Yes, (2) Not addressed & (3) Not addressed:** **Gait speed** was significantly **lower** in fallers than in non-fallers **during ST and DT**. Unlike non-fallers, fallers significantly **reduced their gait speed under DT gait with respect to normal gait**.	Moderate risk of bias
Freire Júnior et al., 2017 [30]	62 community-dwelling older adults: 27 fallers (67.96 ± 5.7 y.; 26 F; MMSE: 25, 95% CI 23.5-26.5) and 35 non-fallers (67.97 ± 4.82 y.; 24 F; MMSE: 26.57, 95% CI 25.63-27.52)	**Retrospective** study; Questionnaire about the history of falls in the 6 months preceding the assessment day; → Fallers = (# of falls = 1)	Motor task: **walking** 8 m at self-selected speed Concurrent tasks: - **verbal fluency task:** naming animals without repeating names - **motor task:** transferring a coin from one pocket to the other	**(1) No, (2) Not addressed & (3) Not addressed:** There was **neither a significant main effect of the faller status nor significant interaction effects between group and walking condition**.	Moderate risk of bias
Verghese et al., 2017	166 high-functioning older adults (74.5 ± 6.07 y.; 85 F; RBANS: 91.56 ± 12): 71 fallers	**Prospective** cohort study;	Motor task:	**(1) Not addressed, (2) Yes & (3) Yes:** **Higher PFC activation levels on fNIRS during DT predicted falls.**	Moderate risk of bias

[98]	(34 with # of falls > 1) and 85 non-fallers	50-month follow-up period (mean follow-up: 33.9 ± 11.9 months)	**walking** at normal pace on an electronic walkway (for 3 continuous loops consisting of 6 straight segments and 5 turns) Concurrent cognitive task: **mental tracking/working memory task:** recitation of alternate letters of the alphabet (under ST: for 30 seconds while standing)	However, **PFC activation during both motor and cognitive ST**, as well as **gait velocity and letter rate during DT** were **not significantly associated with risk of falls**.	
Caetano et al., 2018 [19]	50 healthy community-dwelling older adults: high-risk of falling group (n=22; 77 ± 8 y.; 16 F) and low-risk of falling group (n=28; 72 ± 4 y.; 18 F)	**Retrospective** study; Classification based on falls experienced in the past 12 months and on the PPA score; → High fall-risk group = (history of multiple falls and/or PPA score ≥ 1.5)	Motor task: gait adaptability test (GAT) → **walking** over a 6-m path at self-selected speed under 4 conditions: while avoiding an obstacle, stepping onto close or far targets, or walking without any stimulus on the pathway Concurrent cognitive task: **mental tracking/working memory task:** serial-3 subtraction from a two-digit number	**(1) Yes, (2) Yes & (3) No:** **At least one stepping error in the single GAT and reduced GAT velocity in both ST and DT conditions** were found to **discriminate** low- from high-risk of falling groups and to be **independent predictors of high risk of falling**. The **association between ST GAT errors and fall risk** was **mediated by impaired EF**, while the **association between GAT velocity and fall risk in ST and DT situations** was **mediated by high concern about falling, weak quadriceps strength and impaired EF**. However, **GAT under DT condition did not provide greater predictive power of fall risk over ST GAT**.	Moderate risk of bias
Callisaya et al., 2018 [21]	424 older adults (77.8 ± 6.4 y.; 234 F; RBANS: 93.5 ± 12.6)	**Retrospective** study; Participants were asked if they had fallen in the past year; → Fallers = (# of falls ≥ 1)	Motor task: **walking** on a computerized mat (457.2 cm long) at normal walking speed Concurrent cognitive task: **mental tracking/working memory task:** recitation of alternate letters of the alphabet starting with the letter 'A'	**(1) Not addressed, (2) Yes & (3) No:** **In separate regression models**, falls in previous year were significantly associated with **slower DT walking speed**, **ascending and descending stairs**. However, in the **final model**, **only time for ascending stairs** remained significant.	Moderate risk of bias
Commandeur et al., 2018 [26]	42 community-dwelling older adults: 27 fallers (75.9 ± 3.3 y.; 19 F; MMSE: 28.5 ± 1.6) and 15 non-fallers (75.8 ± 3.4 y.; 6 F; MMSE: 28.5 ± 1.1)	**Retrospective** study; Self-reported falls over the previous 12 months; → Fallers = (# of falls ≥ 1)	Motor task: **walking** there and back (10 ST and 10 DT walking passes) at a self-selected preferred speed along a 6.4 m instrumented walkway Concurrent cognitive task: **mental tracking/working memory task:** serial-7 subtraction aloud from a randomly generated three-digit number	**(1) Not addressed, (2) Yes & (3) Not addressed:** **Larger stride length difference and stride time difference significantly and uniquely contributed to the increase of fall risk.** These DTC gait measures **outperformed traditional clinical tests of strength, mobility and balance, and physiological assessments**.	Low risk of bias
Halliday et al., 2018 [35]	27 older adults: 12 fallers (76.25 ± 3.19 y.; 8 F) and 15 non-fallers (75.93 ± 3.41 y.; 7 F)	**Retrospective** study; Follow-up period: the two-years leading up to the first study visit; → Fallers = (# of falls ≥ 1)	Motor task: **walking** at self-selected, normal walking speed along a 6.4 m instrumented walkway → 10 passes * total recorded walking distance of about 6.1 m	**(1) Yes, (2) Yes & (3) Yes:** **Mean step length, step length CoV and swing time CoV** were significantly **larger** in fallers compared to non-fallers **in DT**, and not in ST. **Step length variability in DT** showed a **significant effect within the logistic regression model**.	Moderate risk of bias

			Concurrent cognitive task: **mental tracking/working memory task:** serial-7 subtraction from a given three-digit starting number		
Howcroft et al., 2018 [42,45]	75 community-dwelling older adults: 28 fallers (75 ± 8.2 y.; 14 F) and 47 non-fallers (75.3 ± 5.5 y.; 30 F)	**Prospective** study (and comparison with retrospective studies from the same group [43,44]); → Fallers = (# of falls ≥ 1 during the 6-month follow-up period)	Motor task: **walking** 7.62 m Concurrent cognitive task: **verbal fluency task**: saying words starting with A, F or S	**(1) Yes, (2) Yes & (3) No:** **For DT gait**, fallers had significantly **lower stance AP COP path CoV and AP FFT first quartile for the head accelerometer** compared to non-fallers, whereas, **during ST**, fallers showed significantly **lower ML FFT first quartile for the left shank accelerometer** as well as **lower superior maximum acceleration for the right shank accelerometer**. Although the **best overall models were based on DT** walking, the **comparison between ST- and DT-gait-based models did not reveal a clearly superior gait assessment for fall-risk prediction** (similar accuracies for the top ST- and DT-gait-based models).	Moderate risk of bias
Minet et al., 2018 [62]	322 older women: 117 fallers from the falls clinic, 99 fallers (79 [76-85] y.; MMSE: 27 [25-29]) and 106 non-fallers (80 [75-86] y.; MMSE: 28 [26-29]) from the community	Observational case-control (**retrospective**) study; Self-reported questionnaire to assess falls history over 1 year; → Once only faller and recurrent fallers (> 1 fall)	Motor task: 4-meter **walking** test at preferred walking speed Concurrent cognitive task: **mental tracking/working memory task:** serial-3 subtractions	**(1) Yes, (2) Not addressed & (3) Not addressed:** **Under both ST and DT**, **gait speed** was significantly **slower** in fallers compared to non-fallers from the community. However, gait speed was **not significantly different between community-dwelling once only fallers and recurrent fallers**.	Moderate risk of bias
Gillain et al., 2019b [32,33]	96 community-dwelling older adults: 35 fallers (69 [67-76] y.; 17 F; MoCA: 27 [26-29]) and 61 non-fallers (70 [67-74] y.; 31 F; MoCA: 28 [26-29])	Longitudinal (**prospective**), observational study; 2-year follow-up; → Fallers = (# of falls ≥ 1)	Motor task: **walking** at self-selected comfortable speed (+ walking at self-selected fast speed) Concurrent cognitive task: **mental tracking/working memory task:** serial-7 subtraction from 100	**(1) Yes, (2) Yes & (3) Inconclusive:** Fallers had **lower gait speed during fast walking ST, shorter stride length during normal speed and fast walking ST and higher symmetry DTC.** Among the discriminative variables, **symmetry DTC** was **the only one significantly related to the risk of falls.** The **model** obtained in [32] **included symmetry DTC, stride length in fast walking ST, stiffness, mean MTC in normal speed walking ST, MTC CoV DTC, MTC variance and mean MTC in fast walking ST, delta1 MTC in DT and gender**.	Low risk of bias

Table 2 Articles about dual tasks involving gait initiation that were included in the systematic literature review. Abbreviations: y. = years; F = females; M = males; # = number; MMSE = Minimal Mental State Examination; RDST = Rapid Dementia Screening Test; EF = executive function; RT = reaction time.

Authors	Population	Falls	Dual-task paradigm	(1) Do DT-related changes or DT performance discriminate fallers from non-fallers? (2) Are DT-related changes or DT performance predictors of falling? (3) Is the DT-related predictive strength superior compared to the ST-related one? (Yes/No/Inconclusive/Not addressed)	Risk of bias via QUIPS tool
Callisaya et al., 2016 [20]	124 older adults: 27 single fallers (71.3 ± 5.3 y.; 13 F), 20 multiple fallers (73.5 ± 9 y.; 11 F) and 77 non-fallers (70.2 ± 6.6 y.; 29 F)	**Prospective** study; Falls questionnaire sent every 2 months for 12 months + falls calendar + phone call; → Fallers = (# of falls ≥ 1) (single fallers or multiple fallers);	Motor task: **starting walking** in response to a buzzer activated at random times Concurrent cognitive task: **mental tracking/working memory task:** 3-serial subtraction	**(1) Not addressed, (2) Yes & (3) No:** **Slower overall GI time under ST and DT, swing time under DT and slower time to first lateral movement under ST increased the risk of multiple falls**. However, **GI under DT did not increase the discrimination of multiple fallers over ST condition**: slower time to first lateral movement under ST showed the strongest association with multiple falls.	Moderate risk of bias

Table 3 Articles about dual tasks involving postural control that were included in the systematic literature review. Abbreviations: y. = years; F = females; M = males; # = number; MMSE = Minimal Mental State Examination; AP = anteroposterior; ML = mediolateral; PCA = Principal Component Analysis; RMS = root mean square; RT = reaction time; COM = center of mass; RANGE = maximum distance between 2 points of the COP time series; MVELO = average velocity of the COP; MDIST = mean distance, average distance from the mean COP; RDIST = RMS distance.

Authors	Population	Falls	Dual-task paradigm	(1) Do DT-related changes or DT performance discriminate fallers from non-fallers? (2) Are DT-related changes or DT performance predictors of falling? (3) Is the DT-related predictive strength superior compared to the ST-related one? (Yes/No/Inconclusive/Not addressed)	Risk of bias via QUIPS tool
Kang et al., 2013 [48]	717 relatively healthy community-dwelling older adults (77.9 ± 5.3 y.; 458 F; MMSE: 27.1 ± 2.6): 131 outdoor fallers, 137 indoor fallers, 129 fallers with both outdoor and indoor falls and 320 non-fallers	**Prospective** study; Falls monitored over 6-36 months; → Fallers = (# of falls ≥ 1)	Motor task: **quiet standing** barefoot with eyes open for 30 s Concurrent cognitive task: **mental tracking/working memory task:** serial-3 subtraction from 500 (individual adaptation of the task in case of difficulty)	**(1) Not addressed, (2) Yes & (3) No:** **Only AP COM RMS was significantly smaller in non-fallers** compared to fallers. **Greater postural stiffness and damping were associated with lower outdoor fall risks**. Furthermore, **greater COM RMS was associated with higher indoor falls**, whereas **greater damping in the AP direction was related to lower rates of indoor falls.** Except for the last predictor, the associations of postural measures with indoor and outdoor fall rates were invariant by direction (AP vs. ML) and by condition (ST vs. DT). → **Measuring postural control under DT did not improve fall prediction**.	Moderate risk of bias
Maranesi et al., 2015 [55]	130 older adults: 45 infrequent fallers (79 ± 6 y.; 26 F; MMSE: 25 ± 3), 18 frequent fallers (81 ± 6 y.; 16 F; MMSE: 25 ± 3) and 67 non-fallers (79 ± 5 y.; 38 F; MMSE: 26 ± 3)	**Retrospective** study; Last year fall history; → Infrequent fallers = 1 or 2 falls, frequent fallers ≥ 2 falls	Motor task: **quiet standing** with eyes open and closed on both a firm and a compliant surface during 30 s Concurrent cognitive task: **mental tracking/working memory task:** serial-7 subtraction (performed while standing with eyes open on a firm surface)	**(1) Yes but…, (2) Not addressed & (3) Not addressed:** **Postural DT on a firm surface** and related posturographic parameters (**RANGE-AP, MVELO-AP and MVELO-ML**) were significantly **different between non-fallers and frequent fallers**, while **RANGE-AP** was also found to be significantly **different between infrequent and frequent fallers**. **However, performing postural ST with eyes open on a compliant surface and using PCA-derived parameters allowed to discriminate between non-fallers and (infrequent and frequent) fallers and between infrequent fallers and frequent fallers.** Indeed, the parameter derived from the first principal component (PC1) was significantly different between all pairs of groups. For this task, PC1 involved posturographic parameters concerning the AP variation in COP displacement: MDIST-AP, RDIST-AP, RANGE-AP.	Moderate risk of bias
Westlake et al., 2016 [102]	23 older adults: 12 fallers (70 ± 5 y.; MMSE = 29) and 11 non-fallers (69 ± 4 y.; MMSE = 30)	**Retrospective** study; Falls history over the last year; → Fallers = (# of falls ≥ 1)	Motor task: maintaining **postural stability** under 2 different perturbation conditions ("quickly grab one handrail and do not take a step"): predictable and unpredictable Concurrent cognitive tasks:	**(1) Yes, (2) Not addressed & (3) Not addressed:** The only significant difference between older adult fallers and non-fallers concerned **grasp errors under both DT conditions**, with a **higher amount of errors** in fallers compared to non-fallers.	Moderate risk of bias

			- **verbal fluency task:** associated verb generation as quickly as possible after having heard a noun - **mental tracking/working memory task:** 1-back verb generation task		
Rinaldi et al., 2017 [76,77]	30 older adults: 15 fallers (70.1 ± 5.1 y.; 15 F; MMSE: 27 ± 3.2) and 15 non-fallers (71.8 ± 5.8 y., 15 F; MMSE: 28 ± 1.3)	**Retrospective** study; 12-month follow-up period prior to data collection; → Fallers = (# of falls ≥ 1)	Motor task: **walking** at self-selected speed (also perform as ST) (or **postural control:** performing the concurrent task while staying stationary → in [77]) Concurrent task: **motor task**: to reach and grasp a dowel with the right hand and without contacting the obstacles and knocking down the support, under different difficulty levels: stable (SB) and unstable (UB) bases without obstacles, stable base with obstacles at short (SSD) and long (SLD) distances, and unstable base with obstacles at short (USD) and long (ULD) distances	**(1) Yes, (2) Not addressed & (3) Not addressed:** In a previous study from the group using the same dataset but other sort of analyses [77], **step width and step duration** were **greater** in fallers than in non-fallers. Furthermore, **step velocity** was **lower** in fallers **in step at dowel contact**. Moreover, fallers exhibited a **greater reduction in AP COM velocity and a significantly earlier minimum AP COM velocity before dowel contact** than non-fallers. Finally, fallers showed **greater AP and ML margins of dynamic stability, a greater movement time and temporal difference between right heel contact and reaching onset, and lower peak wrist velocity, time-to-peak grip aperture only during walking DT, peak grip aperture velocity during postural DT and time-to-peak grip aperture velocity.→ Generalized slowing down in movement performance in fallers.** Here (in [76]), **mean walking speed during both ST and DT** was significantly **lower** in fallers compared to non-fallers. Fallers presented a **higher frequency of grasping the dowel in double support**, whereas **non-fallers** showed a **greater frequency of dowel grasping using a contralateral single support**.→ **Greater decoupling between walking and prehension in fallers.**	Low risk of bias
Zhou et al., 2017 [107]	738 older adults: 460 fallers (78.1 ± 5.5 y.; 292 F) and 278 non-fallers (77.9 ± 5.3 y.; 178 F)	**Prospective** study; Over a follow-up period of 48 months; → Fallers = (# of falls ≥ 1)	Motor task: **quiet standing** barefoot with eyes open for 30 s Concurrent cognitive task: **mental tracking/working memory task:** serial-3 subtraction from 500 (individual adaptation of the task in case of difficulty)	**(1) Yes, (2) Yes & (3) Yes:** Fallers exhibited **lower AP postural sway complexity** (measured by multiscale entropy) **under both ST and DT** in comparison with non-fallers. **AP complexity of postural sway during ST and DT was independently negatively associated with the incidence of future falls.** **During ST**, older adults in the **quintile 1** had a significantly **higher falls rate than those in quintiles 4 and 5**, whereas, **during DT**, those in **quintiles 1,2 and 3 of complexity presented higher fall rates than those in quintiles 4 and 5**. **In the DT condition**, older adults in the **lower quintiles of complexity (quintiles 1, 2 and 3) experienced significantly more falls during the follow-up compared to those in the highest quintile of complexity (quintile 5)**. **DT postural sway complexity**, with its particular sensitivity, was a **better predictor of future falls risk than ST postural sway complexity**.	Moderate risk of bias
Santos et al., 2018 [79]	30 older women: 15 fallers (79 ± 6 y.; 26 F; MMSE: 25 ± 3) and 15 non-fallers (81 ± 6 y.; 16 F; MMSE: 25 ± 3)	**Retrospective** study; 6-month follow-up period; → Fallers = (# of falls ≥ 1).	Motor task: **walking** (also perform as ST) or **postural control** (performing the concurrent task while staying stationary) Concurrent task:	**(1) Yes, (2) Not addressed & (3) Not addressed:** **During ST walking**, **step length** was significantly **smaller** in fallers compared to non-fallers. Fallers were **less accurate** (significantly **larger AP constant error**, particularly **for the walking DT combine with the 8-cm target**) and **slower** (**during the postural**	Moderate risk of bias

			manual task: grasping, transporting and placing the dowel as close as possible to the center of the target, with 4 different levels of difficulty according to target distance (short versus long distance) and target size (target of either 8 or 12 cm)	**DT and for the long distance** in comparison with the walking DT and short distance, respectively) **in the dowel-positioning task** than were non-fallers.	
Uiga et al., 2018 [96]	78 older adults: 34 fallers (69 ± 3.52 y.; 29 F; MMSE: 29.03 ± 0.98) and 36 non-fallers (68.89 ± 3.7 y.; 28 F; MMSE: 29.23 ± 1.11)	**Retrospective** study; Falls history over the last 2 years; → Fallers = (# of falls ≥ 1)	Motor task: 1-minute **quiet standing** Concurrent cognitive task: **discrimination and decision-making task:** tone-counting task → monitoring and subsequently reporting the number of high-pitched tones presented via computer speakers	**(1) Yes, (2) Not addressed & (3) Not addressed:** Regarding traditional COP sway variables, there was a significant effect of group on balance performance, with **greater area of sway**, **SD-ML and SD-AP** in fallers compared to non-fallers. However, **no significant interaction between task condition and group** was observed. Concerning complexity-based COP sway variables, there was no significant group effect and no interaction between group and task condition. Moreover, no significant difference between older adult fallers and non-fallers was found for mean tone-counting accuracy.	Low risk of bias

Table 4 Articles about dual tasks involving turns that were included in the systematic literature review. Abbreviations: y. = years; F = females; M = males; # = number; OR = odds ratio; MMSE = Minimal Mental State Examination; RDST = Rapid Dementia Screening Test; AUC = Area Under the Curve; PSE = Power Spectral Entropy; PSP = Power Spectrum Peak; PSPF = Power Spectrum Peak Frequency; WPSP = Weighted Power Spectrum Peak.

Authors	Population	Falls	Dual-task paradigm	(1) Do DT-related changes or DT performance discriminate fallers from non-fallers? (2) Are DT-related changes or DT performance predictors of falling? (3) Is the DT-related predictive strength superior compared to the ST-related one? (Yes/No/Inconclusive/Not addressed)	Risk of bias via QUIPS tool
Muhaidat et al., 2014 [67]	62 independently ambulant community-dwelling older adults: 13 fallers (82 ± 12 y.; 9 F; MMSE: 29 ± 3) and 49 non-fallers (75 ± 11.5 y.; 32 F; MMSE: 29 ± 2)	**Prospective** study; 6-month follow-up validation cohort study; → Fallers = (# of falls ≥ 1); + falls in the previous year	8 dual-task tests and 1 triple-task test, with **straight walking with or without obstacles**, **walking with turns** and **stair descent** as motor tasks and **motor**, **verbal fluency, mental tracking/working memory**, and **discrimination and decision-making tasks** as concurrent tasks: - straight walking and visuospatial clock task; - walking with turns and naming animals; - walking with turns and counting backwards in 3s; - avoiding stationary obstacles and naming animals; - avoiding a moving obstacle and carrying a cup; - timed Up & Go (TUG) and carrying a cup; - stair descent and naming animals; - walking while talking complex; - straight walking, visuospatial clock task, and carrying a cup	**(1) Not addressed, (2) Yes & (3) Inconclusive**: This multivariate analysis **failed to identify a useful predictive tool**, but gave an indication regarding **the most useful variables in predicting falls in a multivariate analysis**; that is, **time for avoiding a moving obstacle in ST and DT while carrying a cup, time required to perform the walking task in the triple-task test, time for TUG in DT, and absolute difference for TUG time between ST and DT**. **For these 5 variables**, the **ORs** obtained with binary logistic regression were all **statistically significant**. Moreover, in terms of the form of DT outcomes, **absolute difference could be a better predictor of falls than the proportionate difference**.	Moderate risk of bias
Ansai et al., 2016 [3]	67 community-dwelling older adults: 24 fallers (80-85 y.; 18 F; MMSE = 24) and 43 non-fallers (80-83 y.; 27 F; MMSE = 27)	Cross-sectional (**retrospective**) study; Self-report of falls over the past 3 months; → Fallers = (# of falls ≥ 1)	Motor task: **TUG** test (**walking, turning and transfers**) Concurrent tasks: - **mental tracking task/working memory task:** repeating days of the week in reverse order; - **motor task:** grasping a drinking filled with water	**(1) Yes, (2) Not addressed & (3) Not addressed:** Most balance and DT variables were significantly correlated. Fallers **took significantly more time and steps during both TUG tests with cognitive or motor concurrent task.** → **DT-TUG outperformed balance tests regarding prediction of falls.**	Low risk of bias

Ponti et al., 2017 [71]	36 community-dwelling healthy older adults: 18 fallers (75.25 ± 8.2 y.; 15 F; MMSE: 23.75 ± 3.93) and 18 non-fallers (70.94 ± 6.69 y.; 10 F; MMSE: 26.46 ± 4.35)	**Retrospective** study; Participants questioned about their history of falls over the past year	Motor task: **TUG** test Concurrent tasks: - **motor task**: carrying a cup filled with water (TUG-M) - **mental tracking/working memory task**: continuous simple subtraction questions (TUG-C)	**(1) Yes, (2) Yes & (3) Yes:** Regarding frequency domain features, only **lower PSE**, **WPSP2 and WPSP3 related to TUG-C** as well as **lower features fusion**, **lower PSE and PSP differences between the whole signal and the TUG-C**, **lower PSPF difference between TUG and TUG-M**, and **lower WPSP difference between TUG-M and TUG-C** as well as **lower distances fusion** were significantly **able to identify fallers from non-fallers**. Regarding ROC analysis, **the extracted frequency and distance-based features had higher values of AUC, f1-Scores, sensitivity and specificity compared to the traditional parameters** (e.g., completion times) **related to TUG tests**. However, the **best results were allocated to the fusion of distance-based features**. → The use of both distance-based features and fusion might improve the results.	Low risk of bias
Asai et al., 2018 [4,5]	537 community-dwelling older adults: 103 fallers (77.5 ± 6 y.; 68 F; RDST: 9.5 ± 3.1) and 434 non-fallers (76.5 ± 6.4 y.; 278 F; RDST: 9.6 ± 2.8)	**Retrospective** study; Self-administered questionnaire; Definition of a fall: [49].	Motor task: **TUG** test (walking at a comfortable and safe pace) Concurrent cognitive task: **mental tracking/working memory task**: serial-1 subtraction aloud from 100	**(1) Yes, (2) Yes & (3) Yes – additional value:** Fallers took significantly **longer to complete ST-TUG** and presented a **lower DTC value** in comparison with non-fallers. **ST-TUG score and DTC value** were **significantly associated with fall history**. Compared to the other 3 fall risk groups (based on cut-off values), a **higher proposition of older adults from the fall risk group characterized by a slower ST-TUG score and a lower DTC value reported a history of falls**. **Both above mentioned predictors were similarly significantly associated with falls history in the transitional functioning group** (ST-TUG time = 7-16 s), but **not in the well-functioning group** (ST-TUG score < 7 s).	Low risk of bias
Toma-Carus et al., 2019 [93]	367 community-dwelling older adults: 96 fallers (78 F/18 M; 71.5 ± 9/73.5 ± 8 y.; Clock Drawing Test score: 19 ± 2/20 ± 1) and 271 non-fallers (179 F/92 M; 70 ± 7/73 ± 8 y.; Clock Drawing Test score: 19 ± 2/19 ± 1)	Cross-sectional (**retrospective**) study; Fall history over the last year; → Fallers = (# of falls ≥ 1)	Motor task: **TUG** test Concurrent cognitive task: **mental tracking/working memory task:** serial-1 subtraction from 100	**(1) Yes, (2) Yes & (3) Yes:** Among **men**, **mean TUG-DT time spent, mean cognitive stops, mean motor stops, DTC, [TUG-DT time + cognitive stops] and [TUG-DT time + cognitive stops + cognitive errors]** were significantly **higher** in fallers compared to non-fallers. Regarding **women**, only significantly **greater [TUG-DT time + cognitive stops + cognitive errors] and mean motor stops** were characteristic of fallers. In **men**, a **significant AUC for predicting risk of falls** was found for **mean TUG-DT time spent, [TUG-DT time + cognitive stops], [TUG-DT time + cognitive stops + cognitive errors] and DTC**, whereas it was only **for [TUG-DT time + cognitive stops] and [TUG-DT time + cognitive stops + cognitive errors]** in **women**. The **best predictor** (in terms of AUC) was **DTC in men** and **[TUG-DT time + cognitive stops + cognitive errors] in women**.	Low risk of bias
Asai et al., 2020 [5]	649 community-dwelling older adults: 331 young-older adults (60–74 y.), with 78 fallers (72.1 ± 2.9 y.; 53 F; RDST: 10.6 ± 2.5) and 253 non-fallers (71.7 ± 2.8 y.; 164 F; RDST: 11 ± 1.7), and 318 old-older adults (≥ 75 y.),	Longitudinal observation study (**prospective** study); 1-year follow-up	Motor task: **TUG** test (walking at a comfortable and safe pace) Concurrent cognitive task:	**(1) Yes, (2) Yes & (3) Yes – additional value:** **In young-older adults**, fallers took **longer to perform ST-TUG** in comparison with non-fallers. **Old-older adult fallers** showed **lower DTC** than non-fallers. Regarding **predictive power for risk of falls**, **in old older adults**, a **longer ST-TUG time and lower DTC value** were significantly associated with falls occurrence.	Moderate risk of bias

	with 97 fallers (80.4 ± 3.6 y.; 69 F; RDST: 9.3 ± 2.9) and 221 non-fallers (80.8 ± 3.9 y.; 139 F; RDST: 9.1 ± 2.9)		**mental tracking/working memory task**: serial-1 subtraction aloud from 100	→ **DT may provide an additional value in TUG for predicting falls among old-older adults**.	

Click here to view linked References

Supplementary Material

A. *Search Strategies Among the Different Databases*

Table A.1 Search strategies (keywords and filters) related to the different databases used. In bold: MeSH Terms; * for terms with end-truncation; TS = topic; TITLE-ABS-KEY = document title-abstract-keyword.

Database	Keywords & filters - *Gait*	Keywords & filters - *Gait initiation*	Keywords & filters - *Posture*	Keywords & filters - *Turning*
Pubmed/Cochrane CENTRAL	(**locomotion** OR **walking** OR **gait**) AND (**accidental falls** OR faller) AND (**aged** OR **aging**) AND (dual task* OR dual-task* OR **cognition** OR **attention**), Filters: English, Humans, from 2013 - 2020	(gait initiation OR step initiation) AND (**accidental falls** OR faller) AND (**aged** OR **aging**) AND (dual task* OR dual-task* OR **cognition** OR **attention**), Filters: English, Humans, from 2013 - 2020	(**posture** OR **postural balance** OR **standing position**) AND (**accidental falls** OR faller) AND (**aged** OR **aging**) AND (dual task* OR dual-task* OR **cognition** OR **attention**), Filters: English, Humans, from 2013 - 2020	(turns) AND (**accidental falls** OR faller) AND (**aged** OR **aging**) AND (dual task* OR dual-task* OR **cognition** OR **attention**), Filters: English, Humans, from 2013 - 2020
Scopus	(TITLE-ABS-KEY("accidental falls") OR TITLE-ABS-KEY("faller")) AND (TITLE-ABS-KEY("aged") OR TITLE-ABS-KEY("aging")) AND (TITLE-ABS-KEY("cognition") OR TITLE-ABS-KEY("attention") OR TITLE-ABS-KEY("dual task*") OR TITLE-ABS-KEY("dual-task*")) AND (TITLE-ABS-KEY("locomotion") OR TITLE-ABS-KEY("walking") OR TITLE-ABS-KEY("gait")) AND NOT (TITLE-ABS-KEY("Parkinson") OR TITLE-ABS-KEY("Alzheimer") OR TITLE-ABS-KEY("stroke") OR TITLE-ABS-KEY("multiple sclerosis") OR TITLE-ABS-KEY("diabet*") OR TITLE-ABS-KEY("training")) AND (LIMIT-TO (SRCTYPE,"j")) AND (LIMIT-TO (DOCTYPE,"ar")) AND (LIMIT-TO (SUBJAREA,"MEDI") OR LIMIT-TO (SUBJAREA,"HEAL") OR LIMIT-TO (SUBJAREA,"NEUR") OR LIMIT-TO (SUBJAREA,"MULT")) AND (LIMIT-TO (PUBYEAR,2020) OR LIMIT-TO (PUBYEAR,2019) OR LIMIT-TO (PUBYEAR,2018) OR LIMIT-TO (PUBYEAR,2017) OR LIMIT-TO (PUBYEAR,2016) OR LIMIT-TO (PUBYEAR,2015) OR LIMIT-TO (PUBYEAR,2014) OR LIMIT-TO (PUBYEAR,2013)) AND (LIMIT-TO (LANGUAGE,"English"))	(TITLE-ABS-KEY("accidental falls") OR TITLE-ABS-KEY("faller")) AND (TITLE-ABS-KEY("aged") OR TITLE-ABS-KEY("aging")) AND (TITLE-ABS-KEY("cognition") OR TITLE-ABS-KEY("attention") OR TITLE-ABS-KEY("dual task*") OR TITLE-ABS-KEY("dual-task*")) AND (TITLE-ABS-KEY("gait initiation") OR TITLE-ABS-KEY("step initiation")) AND NOT (TITLE-ABS-KEY("Parkinson") OR TITLE-ABS-KEY("Alzheimer") OR TITLE-ABS-KEY("stroke") OR TITLE-ABS-KEY("multiple sclerosis") OR TITLE-ABS-KEY("diabet*") OR TITLE-ABS-KEY("training")) AND (LIMIT-TO (SRCTYPE,"j")) AND (LIMIT-TO (DOCTYPE,"ar")) AND (LIMIT-TO (SUBJAREA,"MEDI") OR LIMIT-TO (SUBJAREA,"HEAL") OR LIMIT-TO (SUBJAREA,"NEUR") OR LIMIT-TO (SUBJAREA,"MULT")) AND (LIMIT-TO (PUBYEAR,2020) OR LIMIT-TO (PUBYEAR,2019) OR LIMIT-TO (PUBYEAR,2018) OR LIMIT-TO (PUBYEAR,2017) OR LIMIT-TO (PUBYEAR,2016) OR LIMIT-TO (PUBYEAR,2015) OR LIMIT-TO (PUBYEAR,2014) OR LIMIT-TO (PUBYEAR,2013)) AND (LIMIT-TO (LANGUAGE,"English"))	(TITLE-ABS-KEY ("accidental falls") OR TITLE-ABS-KEY ("faller")) AND (TITLE-ABS-KEY ("aged") OR TITLE-ABS-KEY ("aging")) AND (TITLE-ABS-KEY ("cognition") OR TITLE-ABS-KEY ("attention") OR TITLE-ABS-KEY ("dual task*") OR TITLE-ABS-KEY ("dual-task*")) AND (TITLE-ABS-KEY ("posture") OR TITLE-ABS-KEY ("postural balance") OR TITLE-ABS-KEY("standing position")) AND NOT (TITLE-ABS-KEY ("Parkinson") OR TITLE-ABS-KEY ("Alzheimer") OR TITLE-ABS-KEY ("stroke") OR TITLE-ABS-KEY ("multiple sclerosis") OR TITLE-ABS-KEY ("diabet*") OR TITLE-ABS-KEY ("training")) AND (LIMIT-TO (SRCTYPE,"j")) AND (LIMIT-TO (DOCTYPE,"ar")) AND (LIMIT-TO (SUBJAREA,"MEDI") OR LIMIT-TO (SUBJAREA,"HEAL") OR LIMIT-TO (SUBJAREA,"NEUR") OR LIMIT-TO (SUBJAREA,"MULT")) AND (LIMIT-TO (PUBYEAR,2020) OR LIMIT-TO (PUBYEAR,2019) OR LIMIT-TO (PUBYEAR,2018) OR LIMIT-TO (PUBYEAR,2017) OR LIMIT-TO (PUBYEAR,2016) OR LIMIT-TO (PUBYEAR,2015) OR LIMIT-TO (PUBYEAR,2014) OR LIMIT-TO (PUBYEAR,2013)) AND (LIMIT-TO (LANGUAGE,"English"))	(TITLE-ABS-KEY ("accidental falls") OR TITLE-ABS-KEY ("faller")) AND (TITLE-ABS-KEY ("aged") OR TITLE-ABS-KEY ("aging")) AND (TITLE-ABS-KEY ("cognition") OR TITLE-ABS-KEY ("attention") OR TITLE-ABS-KEY ("dual task*") OR TITLE-ABS-KEY ("dual-task*")) AND (TITLE-ABS-KEY ("turns")) AND NOT (TITLE-ABS-KEY ("Parkinson") OR TITLE-ABS-KEY ("Alzheimer") OR TITLE-ABS-KEY ("stroke") OR TITLE-ABS-KEY ("multiple sclerosis") OR TITLE-ABS-KEY ("diabet*") OR TITLE-ABS-KEY ("training")) AND (LIMIT-TO (SRCTYPE,"j")) AND (LIMIT-TO (DOCTYPE,"ar")) AND (LIMIT-TO (SUBJAREA,"MEDI") OR LIMIT-TO (SUBJAREA,"HEAL") OR LIMIT-TO (SUBJAREA,"NEUR") OR LIMIT-TO (SUBJAREA,"MULT")) AND (LIMIT-TO (PUBYEAR,2020) OR LIMIT-TO (PUBYEAR,2019) OR LIMIT-TO (PUBYEAR,2018) OR LIMIT-TO (PUBYEAR,2017) OR LIMIT-TO (PUBYEAR,2016) OR LIMIT-TO (PUBYEAR,2015) OR LIMIT-TO (PUBYEAR,2014) OR LIMIT-TO (PUBYEAR,2013)) AND (LIMIT-TO (LANGUAGE,"English"))
Web of Science	TS=(gait OR walking OR locomotion) AND	TS=(gait initiation OR step initiation) AND	TS=(posture OR postural balance OR	TS=(turns) AND TS=(accidental falls OR

	TS=(accidental falls OR faller) AND TS=(aged OR aging) AND TS=(dual-task* OR dual task* OR cognition OR attention) *AND* LANGUAGE: (English) - *Indexes=SCI-EXPANDED, CPCI-S, BKCI-S, ESCI Timespan=2013-2020*	TS=(accidental falls OR faller) AND TS=(aged OR aging) AND TS=(dual-task* OR dual task* OR cognition OR attention) *AND* LANGUAGE: (English) - *Indexes=SCI-EXPANDED, CPCI-S, BKCI-S, ESCI Timespan=2013-2020*	standing position) AND TS=(accidental falls OR faller) AND TS=(aged OR aging) AND TS=(dual-task* OR dual task* OR cognition OR attention) *AND* LANGUAGE: (English) - *Indexes=SCI-EXPANDED, CPCI-S, BKCI-S, ESCI Timespan=2013-2020*	faller) AND TS=(aged OR aging) AND TS=(dual-task* OR dual task* OR cognition OR attention) *AND* LANGUAGE: (English) - *Indexes=SCI-EXPANDED, CPCI-S, BKCI-S, ESCI Timespan=2013-2020*
Google Scholar	Anywhere in the article, with all of the words: (locomotion|walking|gait) (accidental falls|faller) (aged|aging) (cognition|attention|dual task|dual-task) and without the words: -training; articles in English and dated between 2013 and 2020	Anywhere in the article, with all of the words: (gait initiation|step initiation) (accidental falls|faller) (aged|aging) (cognition|attention|dual task|dual-task) and without the words: -training; articles in English and dated between 2013 and 2020	Anywhere in the article, with all of the words: (posture|postural balance|standing position) (accidental falls|faller) (aged|aging) (cognition|attention|dual task|dual-task) and without the words: -training; articles in English and dated between 2013 and 2020	Anywhere in the article, with all of the words: (turns) (accidental falls|faller) (aged|aging) (cognition|attention|dual task|dual-task) and without the words: -training; articles in English and dated between 2013 and 2020

B. Detailed Table of Systematic Reviews

Table B.1 Systematic reviews that have assessed in the last 12 years the power of dual-task walking in predicting risk of falls in healthy older adults.

Authors	Description of the systematic review	Electronic databases & Search terms used for literature search	Inclusion and exclusion criteria	Involved population	Motor & Concurrent cognitive tasks	(1) Is DT performance/DT-related change predictor (or discriminator) of falling? (2) Is the DT-related predictive strength superior compared to the ST-related one? (Yes/No/Inconclusive/Not addressed)
Zijlstra et al., 2008 [80]	7 prospective and 9 retrospective data collection of falls; Retrospective study periods: from 6 to 12 months, prospective follow-up periods: from 3 to 12 months. Studies in common with the other reviews: 6 ([12,36,43,62,71,72]) with [9], 5 ([12,43,63,64,72]]) with [35], 4 ([12,43,62,72]) with [17], 2 ([64,72]) with [49], 1 ([12]) with [53], 2 ([12,64]) with [75].	**Search terms**: (MeSH key terms are the bold ones): (1) (**gait** OR **walking** OR **locomotion** OR **musculoskeletal equilibrium** OR **posture**) (2) #1 AND (**aged** OR **aged, 80 and over** OR **aging**) (3) (**cognition** OR **attention** OR cognitive task(s) OR attention task(s) OR DT(s) OR double task paradigm OR second task(s) OR secondary task(s) (4) #2 AND #3 (5) #4 AND **humans** **Databases**: PubMed, EMBASE, CINALHL, AMED, PsycINFO and Cochrane	**Inclusion criteria**: (1) population: older adults (mean age ≥ 65 years); (2) assessment tool: DT combining gait or other balance task with a cognitive task; (3) design: prospective or retrospective data collection of falls; (4) papers focusing on measures of the ability to predict future falls or to discriminate between fallers and non-fallers for both tasks during DT performance as well as for the single balance and cognitive task; (5) classification of fallers and non-fallers based on actual fall events. **Exclusion criteria**: Individual abstracts, review articles, studies evaluating sitting balance performance, case studies, letters to the editor and studies with subjective scoring system for the assessment of DT performance. *Dates of publication: up to 2006*	Only 6 retrospective studies and 2 prospective studies include from 30 to 380 healthy older people (mean age ≥ 65 years) without a specific pathology or medical condition.	**Motor task**: Straight **walking**, **quiet stance** with different surface and sensory conditions, walking tasks including transfers and **turns** (e.g., TUG). Measures: postural sway, speed, gait measures. **Cognitive task**: -**Verbal fluency tasks**: sentence completion, animals or professions naming; - **Discrimination and decision-making tasks***:* Judgment of Line Orientation, phoneme monitoring, Stroop's colored words test, auditory choice reaction time task; - **Mental tracking/working memory tasks**: backward counting, serial subtractions/additions, remembering a shopping list, listening to a text and answering multiple-choices questions; - **Reaction time task**: simple auditory reaction time. Measures: speed and accuracy.	**(1) Yes & (2) Inconclusive:** In most cases, specificity and predictive values of the DT were moderate or high whereas sensitivity was low. Moreover, while one retrospective [19] and one prospective [4] study reported similar odds ratios for DT compared to ST and an additional retrospective study [62] showed that ST and DT have similar value for discriminating between fallers and non-fallers, two other prospective studies [11,72] suggested an added value of DT conditions over ST regarding prediction of falls. However, any conclusion could not be made because of incomplete comparisons of single and dual walking/balance tasks, and due to the global heterogeneity of the studies.

Beauchet et al., 2009 [9]	Systematic review including 15 studies: 3 retrospective studies and 12 prospective ones; Retrospective study periods: from 6 to 12 months, prospective follow-up periods: from 50 days to 12 months. Studies in common with the other reviews: 6 ([12,36,43,62,71,72]) with [80], 8 ([7,8,10,12,21,40,43,72]) with [35], 12 ([7,8,10,12,21,40,43–45,62,65,72]) with [17], 4 ([7,8,40,72]) with [49], 4 ([7,8,10,12]) with [53], 2 ([8,12]) with [75].	**Search terms**: MeSH terms: "accidental fall" and "aged" or "aged, 80 and over" combined with the terms "DT", "dual tasking", "gait", "walking", "fall" and "falling" **Databases**: English and French Medline and Cochrane library	**Inclusion criteria**: observational studies, retrospective or prospective data collection of falls, number of falls and motor performance under ST and DT as outcomes measures, subjects with mean age of 65and older, and provided enrolment methods, exact procedures of dual tasking and discriminative or predictive values of falls. *Dates of publication: from March 1997 to April 2008*	From 30 to 380 subjects per study; Older adults and frail older adults with mean age of 65 and older. **Note:** In some studies, some subjects exhibit cognitive impairment, dementia, stroke or previous stroke, lower limb neuropathy, depression, or pain in lower limb.	**Motor task**: Various DT conditions with **walking** as main task, some walking tasks including transfers and **turns** (e.g., TUG). Measures: walking time, stop walking, coefficient of variation of stride time variability, walking speed. **Concurrent task**: - **Mental tracking/working memory tasks**: backward counting, reciting alternate letters from the alphabet, simple calculations; - **Verbal fluency tasks**: conversation, recitation of names of animals and professions, or alphabet; - **Discrimination and decision-making tasks**: visuospatial decision task; - **Motor tasks**: carrying a glass of water. Measures: increase backward counting performance.	**(1) Yet & (2) Not addressed**: Despite few conflicting reports probably because of limited sample sizes, study samples heterogeneity, too short follow-up periods or lack of standardization in DT paradigms and outcomes measures, most involved studies (and the pooled odds ratio) showed that DT-related changes are significantly associated with an increased risk of falling in older adults.
Hsu et al., 2012 [35]	Systematic review including 25 studies, with 16 DT studies: 7 prospective studies and 9 cross-sectional ones; Prospective follow-up periods: from 6 months to 2 years. Studies in common with the other reviews: 5 ([12,43,63,64,72]) with [80], 8 ([7,8,10,12,21,40,43,72]) with [9], 9 ([7,8,10,12,21,29,40,43,72]) with [17], 7 [7,8,29,40,42,64,72]) with	**Search terms**: Search and MeSH terms: cognition, executive functions, DT, and falls **Databases**: MEDLINE, Pubmed, and EMBASE	**Exclusion criteria**: studies that did not examine specific cognitive processes (e.g., only measured global cognitive function), intervention studies that focused on improving cognitive function or reducing falls, protocol studies, studies that did not include falls or falls risk, any case report or case series studies, and samples which included those with significant neurodegenerative disease (e.g., Alzheimer's disease). *Dates of publication: from 1948*	From 27 to 380 subjects per DT study; Adults aged 60 years or older from community-dwelling, senior housing facility, residential care, and geriatric rehabilitation hospital. **Note:** In some studies, some subjects exhibit mild/moderate cognitive	**Motor task**: Physical performance task, such as **walking** (including sometimes transfers and **turns**), **maintaining stability** under various conditions, or lower limb maximal strength test. Measures: walking speed, mean walking time, swing time average, gait variability, stride time variability, swing time variability, postural recovery, postural stability, maximal isometric leg strength. **Cognitive task**: - **Mental tracking/working**	**(1) Yes & (2) Inconclusive**: Most studies found a strong association between DT performance on the one hand, and falls or falls risk on the other hand. However, over 16 DT studies, one study [10] found a positive association between better DT performance and falls, whereas another study [7] did not find any predictive power of DT performance regarding falls (based on a multiple logistic regression model) unlike ST performance, and a third study [12] observed a similar predictive strength for DT performance as for ST performance.

	[49], 5 ([7,8,10,12,29]) with [53], 3 ([8,12,64]) with [75].		*to May 3, 2011*	impairment, dementia, stroke or previous stroke, lower limb neuropathy, depression, or pain in lower limb.	**memory tasks**: counting backwards, serial subtraction, reciting alternate letters of the alphabet, simple and complex calculations; -**Verbal fluency tasks**: conversation, sentence completion, recitation of names of animals and professions, or alphabet; - **Discrimination and decision-making tasks**: auditory choice reaction time task, visuospatial decision task, perceptual matching/judgment of line orientation, listen to a text and phoneme monitoring; - **Reaction time task**: reaction time on push-button task. Measures: auditory choice reaction time, accuracy in backward counting, number of correct calculations.	
Chu et al., 2013 [17]	Systematic review including 2 retrospective studies and 13 articles using a prospective design; Retrospective study periods: from 6 to 12 months, prospective follow-up periods: from 29.6 ± 25.9 days to 2 years. Studies in common with the other reviews: 4 ([12,43,62,72]) with [80], 12 ([7,8,10,12,21,40,43–45,62,65,72]) with [9], 9 ([7,8,10,12,21,29,40,43,72]) with [35], 7 ([7,8,29,40,54,72,77]) with	**Search terms**: (MeSH key terms are the bold ones): (**aged** OR **aged 80 and over** OR elderly OR **frail elderly**) and (**gait[s]** OR **walking** OR ambulation OR **locomotion**) and (**accidental fall[s]** OR fall[s]) and (**attention** OR **cognition** OR DT[s] OR attention task[s] OR cognitive task[s] OR secondary task[s] OR double task paradigm) **Databases**: Medline, PubMed, CINAHL, Cochrane Central Register of Controlled Trails and	**Inclusion criteria**: DT paradigm used to discriminate fallers and non-fallers or to predict falls; ground walking as the postural task of the DT paradigm; and mean age of 60 years or older for the sample. **Exclusion criteria**: dissertation theses, review articles or conference abstracts; articles that focused on a single population with a specific diagnosis, such as stroke or arthritis; intervention studies; and articles that did not report discriminative or predictive values of falls. *Dates of publication: up to May 2011*	From 30 to 380 subjects per DT study; Adults aged 60 years or older from senior housing facilities, inpatients, and community-dwelling elderly. **Note:** In some studies, some subjects exhibit cognitive impairment, dementia, stroke or previous stroke, lower limb neuropathy, depression, or pain in lower limb.	**Motor task**: Straight **walking** tasks, **turn** walking and TUG. Measures: walking time, walking speed, coefficient of strike time variation, swing time variability, mean step width, number of stop walking. **Concurrent task**: **- Mental tracking/working memory tasks**: counting backwards, serial subtraction, reciting alternate letters of the alphabet, simple calculations; - **Verbal fluency tasks**: conversation, recitation of names of animals and professions, or alphabet; - **Discrimination and decision-making task**: visuospatial decision	**(1) Yes & (2) Not addressed**: Contrary to verbal fluency tasks and manual tasks, mental tracking tasks were the only type of concurrent tasks related to a significant odds ratio, thus to a significant predictive strength for falls. Besides, the complexity of a specific concurrent task needs to be appropriately chosen for the studied population in order to obtain similar odds ratio independently from the subjects. Finally, the biggest limitation of the review is the substantial heterogeneity between studies.

	[49], 7 [[7,8,10,12,29,54,77]) with [53], 3 ([8,12,54]) with [75].	PsycINFO			task; - **Reaction time task**: reaction time on push-button task; - **Motor tasks**: carrying a glass of water/coffee cup and saucer/tray with a ball. Measures: reaction time, accuracy, speed.	
Menant et al., 2014 [49]	Systematic review and meta-analysis; 30 articles (11 prospective studies and 19 retrospective studies) and 33 samples; Follow-up periods: from 4 to 24 months. Studies in common with the other reviews: 2 ([64,72]) with [80], 4 ([7,8,40,72]) with [9], 7 ([7,8,29,40,42,64,72]) with [35], 7 ([7,8,29,40,54,72,77]) with [17], 5 ([7,8,29,54,77]) with [53], 8 ([6,8,20,54,57,58,64,78]) with [75].	**Search terms**: (MeSH key terms are the bold ones): 1. **gait** OR **walking** OR locomotion 2. falls OR **accidental falls** OR falling OR faller 3. **aged** OR **aged, 80 and over** OR aging OR ageing 4. DT* OR D-T* OR cognition OR attention 5. #1 AND #2 AND #3 AND #4 **Databases**: PubMed, Ovid MEDLINE, EMBASE, PsycINFO, CINAHL, Scopus and Cochrane Central Register of Controlled Trials	**Inclusion criteria**: studies which evaluated gait at self-selected speed under ST and DT conditions in older people to either: (1) predict falls, or (2) discriminate between fallers and non-fallers based on retrospective data collection. **Exclusion criteria**: exclusion if: (1) individual abstracts, case studies or reviews; (2) focus on patient groups (e.g., PD, stroke, etc.) other than cognitive impairment; (3) participants' mean age less than 65 years or all participants younger than 60 years old; (4) the walking task not involving time or gait speed as an outcome; (5) not a cognitive task as the secondary task; (6) subjective scoring systems to assess DT performance; (7) publications in languages other than Dutch, English, French or German. *Dates of publication: from 2008 to February 2013*	From 11 to 1308 participants per sample; Mean age ≥ 65 years or participants older than 60 years; Community-dwellers, outpatients from a geriatrics department, participants from senior housing facilities or intermediate care hostels, and geriatrics and Alzheimer's care unit inpatients; 12 studies with a small percentage or all of the subjects having cognitive impairments; 16 studies with slow walkers (< 1 m/s).	**Motor task**: Straight line **walking** including sometimes a **turn**. Measures: walking speed. **Cognitive task**: Each study comprised one, two or more types of secondary cognitive tasks: mainly **mental tracking/working memory tasks** (counting backwards, reciting alternate letters from the alphabet, serial subtraction, addition/subtraction) and **verbal fluency tasks** (enumeration of animal names, enumeration of words starting with a specific letter) and, to a lesser extent, **discrimination and decision-making tasks** (auditory Stroop task, listening to a randomized audio sequence for "X" and repeating the letter aloud).	**(1) Yes & (2) No*:** Gait speed did not have a significantly better predictive value for falls in a DT compared to a ST paradigm, but both paradigms were equivalent in discriminating fallers from non-fallers based on gait speed assessments. Moreover, the latter results stayed invariant when only prospective falls studies/ subgroups of people with fast gait speed, slow gait speed or with cognitive impairment/ a specific type of concurrent task (mental tracking tasks vs. verbal fluency tasks)/ studies with straight line walking were taken into account. *This answer needs to be taken into account with caution. Indeed, due to a majority of retrospective designs for the reporting of fall history and the analysis of mean difference (an appropriate statistical measure for discriminative ability), it is rather the discriminative power of DT performance (compared to the one of ST) that has been assessed, instead of its predictive value.
Muir-Hunter and Wittwer, 2016 [53]	10 articles with prospective cohort studies that lasted at least 1 year and were based on 7 independent samples.	**Search terms**: MeSH subject terms and keywords: "accidental falls, falling, prospective studies,	**Inclusion criteria**: (1) sample participants aged ≥ 60 years; (2) prospective cohort design with a duration of at least 1year; (3) samples	From 100 (with 98% of subjects available for assessment at the end of the study) to	**Motor task**: Main tasks included **walking** (combining sometimes transfers and **turns**), **quiet stance** and **stepping reaction responses** in	**(1) Yes & (2) Inconclusive**: Although most studies reported DT performance related to falls, 3 of them [8,29,51] showed a stronger association between DT performance and future fall risk

	Studies in common with the other reviews: 1 ([12]) with [80], 4 ([7,8,10,12]) with [9], 5 ([7,8,10,12,29]) with [35], 7 ([7,8,10,12,29,54,77]) with [17], 5 ([7,8,29,54,77]) with [49], 4 ([8,12,51,54]) with [75].	aged, aged80 and over, elderly, aging, gait, postural balance, DT, cognition and attention" **Databases**: MEDLINE, Pubmed and EMBASE	comprised community-dwelling individuals alone; (4) "falls" as the primary study outcome, including "any fall", "recurrent falls" and "injurious falls", and the association between the DT test and future fall risk evaluated in statistical analysis; (5) DT assessment detailed explicitly in the methods section ; (6) reported inclusion and exclusion criteria and demographic information; and (7) confounding factors reported and used in multi-variable regression analysis to generate adjusted risk estimates. *Dates of publication: from January 1998 to September 2013*	1038 participants included in each study; Community-dwelling participants aged ≥ 60 years.	standing. Measures: number of steps, number of complete stops, mean velocity, mean and variability of walking time, swing time, step length, step width and double support time, amplitude and time of COP during step initiation, amplitude of COP during quiet stance. **Concurrent task**: - **Mental tracking/working memory tasks**: counting backwards, serial subtraction; -**Verbal fluency tasks**: recitation of names of animals or professions; - **Discrimination and decision-making task**: Stroop test; - **Motor tasks**: carrying a cup and saucer/tray/tray with a cup and saucer/tray with a ball. Measures: accuracy, speed (e.g., number of names per minute, number of enumerated figures).	than with ST, while 2 additional studies [12,48] did not find any added predictive value for falls in a DT compared to a ST paradigm and 2 others [7,66] even assigned a better predictive power to ST performance. All the studies in favor of the superiority of the DT included a straight (or up and down a hall) walking task. The ones that rather highlighted the use of ST for fall prediction involved respectively a straight walking task, a fast walking and returning task, measures of maximal postural sway during quiet standing under DT conditions and the assessment of stepping reaction responses in standing during a DT situation.
Wollesen et al., 2019 [75]	Systematic review and meta-analysis including 15 and 11 studies respectively, 6 of the 15 studies presenting a prospective design; Retrospective study periods: from 1 to 24 months, prospective follow-up periods: from 12 to 66 months. Studies in common with the other reviews: 2 ([12,64]) with [80] 2 ([8,12]) with [9], 3 ([8,12,64]) with [35], 3 ([8,12,54]) with [17],	**Search terms**: 1. "Age" or "old$" or "elder$" or "aged" or "advanced age" or "senior$" or "geriatric$" or "eldest" or "aging" or "gerontic" or "faller$" or "fear of falling" 2. "corresponding task$" or "coupled task$" or "dual task$" or "dual task paradigm$" or "secondary task" or "conflicting task" or "task prioritisation" or "inattentional	**Inclusion criteria**: (1) population: older adults (mean age ≥ 60 years) with a previous fall; (2) DT paradigm used to discriminate fallers from non-fallers; (3) primary motor task: straight over ground walking at self-selected speed; (4) outcome measures: gait measurements during both ST- and DT-performance or the DT effect on gait performance (more than one gait cycle); (5) clear description of the DT situation; (6) report of adequate data to calculate effect sizes either from descriptive or inferential	From 16 to 1350 healthy older people (mean age between 67 and 87 years) included in each study.	**Motor task**: Straight over ground **walking** at self-selected speed. Measures: cadence, walking speed, gait variability, walking time, stride length, step length, stride length CV, stride time, step time, stride time CV, single-support time/phase, double-support time/phase, stride width, step width, stride width CV, number of strides, number of steps, stance time, swing time, average swing time, swing time variability CV, STV, ML RMS, AP RMS, standardized ML RMS, standardized AP RMS, COP path, min COP velocity, mean COP velocity, median COP velocity,	**(1) Yes & (2) No*:** The meta-analysis revealed significant mean difference between fallers and non-fallers for both ST and DT gait speed, with a reduced performance for fallers. However, no significant mean difference in DTC on gait speed or on the cognitive task performance (considering or not the cognitive task domain) was observed between fallers and non-fallers. Only trends for higher decrements in gait speed for fallers compared to non-fallers under DT conditions, as well as increased DTC in fallers for verbal fluency and motor DT were showed. *This answer needs to be taken into account with caution. Indeed, due to a majority of retrospective designs for the reporting of fall

	8 ([6,8,20,54,57,58,64,78]) with [49], 4 ([8,12,51,54]) with [53].	blindness" 3. "gait" or "step length" or "cadence" or "step count" or "step width" or "stance time" or "swing time" or "single support time" or "stride time" or "stride width" or "stride length" or "gait line" or "maximum force forefoot" or "maximum force midfoot" or "maximum force heel" or "double support time" or "gait speed" or "stride speed" or "motion" or "movement$" or "motor$" or "locomotion" or "walking" or "balance" or "posture" not "slipping" (not "perturbation") 4. "cognitive" or "neurocognitive" or "cognition$" or "executive" or "processing" or "spatial" or "visuospatial" or "memory" or "reaction$" or "speed" or "decision-making" or "mental" or "attention" or "cognitive-motor" or "motor-cognitive" or "reaction$" or "planning" or inhibition 5. Combination of 1 and 2 and 3 and 4 **Databases**:	statistics; (7) inclusion of interventional studies if the DT effect on gait at baseline if reported. **Exclusion criteria**: (1) population with brain injuries or diagnosed cognitive decline, physical impairments (e.g., using a cane or walker) or chronic diseases such as multiple sclerosis or PD; (2) studies with a secondary analysis of previous reported results; (3) publications in languages other than English and German. *Dates of publication: from 1946 (MEDLINE)/1806 (PsycINFO)/1974 (EMBASE) to 2019 (Week 20)*		symmetry index, impulse (foot strike to first peak, min to second peak, second peak to foot off, foot strike), stride frequency, stride regularity, number of complete stops. **Cognitive task**: - **Verbal fluency tasks**: recitation of letters of the alphabet, animals or professions (starting or not with a specific letter), enumeration of words starting with a specific letter; - **Discrimination and decision-making tasks**: Stroop task, clock task; - **Mental tracking/working memory tasks**: backward counting, listening and answering questions; - **Motor tasks**: carrying a cup/glass/tray.	history and the analysis of mean difference (an appropriate statistical measure for discriminative ability), it is rather the discriminative power of DT performance (compared to the one of ST) that has been assessed, instead of its predictive value. Here, there is no additional benefit of DT walking as a measurement to discriminate fallers from non-fallers compared to ST walking.

		MEDLINE, PsycINFO and EMBASE				

C. Detailed Table of Results from the Systematic Literature Review Regarding Walking Dual Tasks

Table C.1 Articles regarding walking dual tasks that were included in the systematic literature review. Abbreviations: y. = years; F = females; M = males; # = number; GDS = Geriatric Depression Scale; HR = hazard ratio; OR = odds ratio; CI = confidence interval; MMSE = Minimal Mental State Examination; SPPB = Short Physical Performance Battery; POMA = Performance Oriented Mobility Assessment; PPV = Positive Predictive Value; NPV = Negative Predictive Value; 6MWT = Six Minute Walk Test; BESTest = Balance Evaluation Systems Test; CT = cognitive task; MT = motor task; AP = anteroposterior; ML = mediolateral; PCA = Principal Component Analysis; AUC = Area Under the Curve; CoV = coefficient of variation; PFC = prefrontal cortex; RBANS = Repeatable Battery for the Assessment of Neuropsychological Status; PPA = Physiological Profile Assessment; TMT = Trail Making Test; IconFES = Iconographical-Fall Efficacy Scale; MSIT = Multi-Source Interference Task; EF = executive function.

Authors	**Population**	**Falls**	**Dual-task paradigm & discriminative/predictive analysis**	**(1) Do DT-related changes or DT performance discriminate fallers from non-fallers?** **(2) Are DT-related changes or DT performance predictors of falling?** **(3) Is the DT-related predictive strength superior compared to the ST-related one?** **(Yes/No/Inconclusive/Not addressed)**	**Risk of bias via QUIPS tool (High H, Moderate M, Low L risk of bias)**
Ayers et al., 2014 [5]	646 community-dwelling older adults: 337 fallers (80.5 ± 5.4 y.; 219 F; Blessed score: 1.7 ± 1.5; normal walking velocity: 94.3 ± 22.7 cm/s) and 309 non-fallers (79.2 ± 5.5 y.; 176 F; Blessed Score: 1.7 ± 1.6; normal walking velocity: 95.8 ± 22.6 cm/s); Inclusion criteria: aged 70 years-old and older, living in the community; Exclusion criteria: severe auditory or visual loss, inability to ambulate, institutionalization, people with significant cognitive impairment (Blessed Score > 6).	**Prospective** study; Mean follow-up of 2.6 years with annual clinical, cognitive and mobility assessments and telephone interviews at baseline and every 2-3 months to assess function and falls; →Fallers = (# of falls ≥ 1) during the follow-up period; Definition of a fall: "unintentionally coming down to the floor or a lower level not due to a major intrinsic or extrinsic event" [67].	Motor task: **walking** 4.6 m at normal pace (+ 0.914 m from either end of the walkway edge) Concurrent cognitive task: **mental tracking/working memory task:** reciting alternate letters of the alphabet Instructions: "pay equal attention to walking and talking" Independent variables & analysis: gait variables at baseline: velocity, cadence, step length, swing, stance, double support, step time variability, swing time variability; (PCA &) Cox proportional hazards models → HR (95% CI)	**(1) Not addressed, (2) Yes & (3) Yes:** In a Cox proportional hazard model adjusted for gender, age and education, **step length in DT condition** was the only individual gait parameter that predicted falls, being **shorter** in fallers compared to non-fallers (HR = 0.989, 95% CI = 0.98-0.99, p = 0.034). In Cox proportional hazard models adjusted for gender, age, education, Illness Index, prescription medicines, GDS, Blessed Score, chair rise test, clinical gait abnormalities, baseline prevalence of previous falls, normal velocity during ST and normal stride length variability during ST, **poorer performance in the DT "pace" domain (including DT velocity and step length)** remained a significant predictor of falls (HR = 1.312, 95% CI = 1.11-1.55, p = 0.002). The inclusion of the two last confounding variables allowed concluding for an **incremental validity of DT over ST walking assessment in the prediction of falls**. However, DTC measured as change in gait velocity between DT and ST conditions did not predict falls. Limitations: difficult generalization to older adults who are institutionalized or with cognitive impairments.	1) M (exclusion criteria missed neurological diseases) 2) L 3) L 4) L 5) L 6) L → Low risk of bias
Hirashima et al., 2015 [30]	92 volunteers from a community senior club: 16 fallers (78.1 ± 5.6 y.; 13 F; MMSE: 28.1 ± 1.6; TUG: 8.3 ± 1.1 s) and 76 non-fallers (74.9 ±	**Prospective** cohort study; Over a follow-up period of 12 months using monthly postal surveys and	Motor task: **walking** 60 m (10 m walkway with 3 returns) at usual speed Concurrent cognitive task:	**(1) Yes, (2) Yes & (3) Not addressed:** Fallers and non-fallers were not significantly different in terms of walking time during ST and DT. There is no significant influence of age on the incidence of injurious	1) L 2) L 3) L

	5.3 y.; 65 F; MMSE: 28.1 ± 1.7; TUG: 8.4 ± 1.5 s); Inclusion criteria: aged 65 years-old and older, living independently in the community, ability to walk approximately 500 m without a cane; Exclusion criteria: MMSE < 25, neurological and/or orthopedic disorders, previous operations on the spine and/or lower extremities.	telephone calls; → Fallers = (injured because of falls or # of falls ≥ 2); Definition of a fall: "accidental contact of any body part, except for the plantar, with a low area such as the floor or the ground"[23].	**discrimination and decision-making task**: not stepping on the unequal lines Independent variables & analysis: time and number of missteps recorded every 20, 40 and 60 m; for group (fallers vs. non-fallers) comparisons at baseline: unpaired t-tests or Mann-Whitney U tests + for comparison between misstep and non-misstep groups and between age groups: Kaplan-Meier survival curves and log-rank tests	falls or more or equal to 2 falls. However, fallers and non-fallers significantly differed in terms of the presence of missteps at 40 m and 60 m (p = 0.041 and 0.035, respectively). Subjects who had made **missteps during the DT test with an extended walking distance of ≥ 40 m** were significantly more likely to be fallers (p = 0.042 at 40 m and p = 0.038 at 60 m, as results of the log-rank tests). Limitations: No direct comparison between ST and DT concerning sensitivity and specificity of predicting falls, unclear inter-rater reliability of the DT test.	4) L 5) L 6) L → Low risk of bias
MacAulay et al., 2015 [46]	416 relatively healthy and cognitively intact older adults, 67.5% female, primarily Caucasian, with normal or corrected vision: 81 fallers (69.6 ± 6.81 y.; initial MMSE: 29.47 ± 0.87; initial SPPB: 11.04 ± 1.4) and 312 non-fallers (70.13 ± 6.62 y.; initial MMSE: 29.25 ± 1.02; initial SPPB: 11.02 ± 1.19); Inclusion criteria: aged 60 years-old and older; Exclusion criteria: GDS ≥ 6; a history of neurological or untreated health conditions that might cause cognitive impairment.	Longitudinal (**prospective**) study; Structured clinical interview after 1 year in order to obtain participant's fall history for the past year; → Fallers = (# of falls ≥ 1); Definition of a fall: "times that individuals unexpectedly lost their balance and unintentionally came unto rest on the ground, floor or other object; events in which participants were able to regain their balance did not count as a fall (e.g., tripping but catching oneself before falling onto the floor)" [41].	Motor task: straight **walking** at normal everyday walking speed Concurrent cognitive task: **mental tracking/working memory task**: spelling a word of 5 letters in length backwards aloud Independent variables & analysis: stride length, step time → average stride length and step time scores; mixed-design repeated measures ANCOVAs for group differences during ST and DT at both time points + partial correlations	**(1) Yes, (2) Not addressed & (3) Not addressed:** Fallers exhibited **shorter stride length** than non-fallers within both walking task conditions (**ST and DT**), even when sex, age and height were controlled (F(1,405) = 15.8, p < 0.001). There was **no significant interaction between group and task conditions on gait stride length**. Shorter strides during DT at follow-up were predicted by worse executive attention/processing speed performance 1 year before (r = 0.24, p < 0.001). Limitations: too specific sample (generally college educated participants, predominantly white, with a higher proportion of females), time frame limited to 1-year, potential unreliability of retrospective clinical interview after one year.	1) L 2) L 3) L 4) L 5) L 6) L → Low risk of bias
Gimmon et al., 2016 [26]	160 older adults: 61 fallers (79.4 ± 5.7 y.; 49 F; MMSE: 28.19 ± 1.53; POMA total score: 26.09 ± 2.15) and 99 non-fallers (81.5 ± 5 y.; 69 F; MMSE: 27.9 ± 1.65; POMA total score: 26.69 ± 1.69); Inclusion criteria: aged 65	Participants asked to **retrospectively** recall fall events during the past year; → Fallers = (# of falls ≥ 1); Definition of a fall: "an event which results in a	Motor task: narrow path **walking** test = walking at a comfortable pace within a 6 m long narrow path Concurrent cognitive tasks: 3 **mental tracking/working memory tasks**: reciting the days of the week backwards, reciting the months of the year backwards, serial-5 subtraction loudly	**(1) Yes, (2) No & (3) No:** **Trial velocity during ST** remained significantly **slower** in fallers compared to non-fallers, even after the gait parameter was adjusted for age, sex and fear of falling (F = 11.498, p < 0.001). Therefore, trial velocity during ST was identified as a potential identifier of falls. There was no significant interaction between group and task. Indeed, among both groups, gait speed decreased during DT. However, **no**	1) L 2) L 3) L 4) L 5) L 6) L

	years-old and older, ability to walk independently, MMSE > 24; Exclusion criteria: serious visual impairment, severe cardio-vascular disease, terminal diseases, Menier and substantial pain, and severe gait impairment due to focal lower limb muscle weakness or palsy, lower limb amputation or joint arthrodesis, or neurological diseases.	person coming to rest inadvertently on the ground or other lower level, regardless of whether an injury was sustained" [68].	from 100 to 50 Instructions: "to walk at their comfortable pace without stepping outside the narrow path" and "to perform both tasks as best as they can" Independent variables & analysis: number of steps during each trial, trial time, trial velocity, ML instability (i.e., number of step errors), and number of cognitive task errors during ST (sitting) and DT; 2-way ANOVA (with group as between-subjects factor and with repeated measures on the within-subject factor that is task) + 2-way ANCOVA (group as between-subjects factor and adjustment by age, sex and fear of falling) + AUC/validity, sensitivity, specificity and PPV related to ROC curve in ST and DT	**added value of DT condition over ST condition in identification of fallers** has been showed. Predictive abilities: **ST trial velocity** ≥ 0.78 m/s vs. DT trial velocity ≥ 0.46 m/s: sensitivity: 77.5% vs. 70.2%; specificity: 57.4% vs. 55%; AUC/validity: 0.69 **(p = 0.002)** vs. 0.62 (p = 0.067); PPV: 53.9% for ST gait speed. Limitations: small sample size, retrospective study, cognitive task not reflecting a realistic life performance, ST condition can be perceived as a motor-motor DT.	→ Low risk of bias
Howcroft et al., 2016 [32,33]	100 community-dwelling older adults: 24 fallers (76.3 ± 7 y.; 11 F; 6MWT distance: 446.6 ± 101.4 m) and 76 non-fallers (75.5 ± 6.6; 45 F; 6MWT distance: 455.8 ± 102.4 m); Inclusion criteria: aged 65 years-old and older, living in the community; Exclusion criteria: cognitive disorder, inability to walk for 6 minutes without an assistive device.	**Retrospective** study; Classification of fallers and non-fallers based on 6-month retrospective fall occurrences; → Fallers = (# of falls ≥ 1); Definition of a fall: [68].	Motor task: **walking** 7.62 m Concurrent cognitive task: **verbal fluency task**: saying words starting with A, F or S Independent variables & analysis: gait velocities for ST and DT trials; temporal, impulse and COP path-related variables from measurements performed via pressure-sensing insoles; descriptive statistics, temporal features, FFT quartile, ratio of even to odd harmonics (REOH) and maximum Lyapunov exponent (MLE) as accelerometer-derived parameters; a) for each variable: mixed-design ANOVA test, with a 2-factor within-subject walking condition (ST,DT) and a 2-factor between-subjects faller status condition (faller, non-faller); post-hoc tests for comparing walking conditions: Wilcoxon Signed-Rank test or paired t-test; post-hoc tests for comparing faller status conditions: Mann-Whitney U test, independent t-test or Welch's t-test; b) 3 classifier models: multi-layer perceptron neutral network, naïve Bayesian, support vector machine; model evaluation → accuracy, specificity, sensitivity, PPV, NPV, F1 score, Matthew's Correlation	**(1) Yes, (2) Yes & (3) No:** a) Regarding pressure-sensing insole measures, for both DT and ST gait data, no significant differences were found between fallers and non-fallers. Concerning accelerometer-derived parameters, fallers showed significantly **greater head posterior standard deviation** (p = 0.025) **and decreased posterior pelvis AP REOH** (p = 0.023) **during ST**, and **greater posterior pelvis vertical MLE** (p = 0.017) **during DT gait**. b) In the context of models of wearable-sensor based fall-risk classification in older adults, **ST sensor-based gait assessment models outperformed models based on DT walking** or clinical assessment data. Limitations: retrospective fall occurrence as the criterion for classification → potential inaccurate recall of falls + potential changes to gait patterns.	1) H (no reporting of global cognitive function - even if self-reported cognitive disorder was an exclusion criterion - or potential neurological disorders, and no baseline comparison of demographic data between fallers and non-fallers) 2) L 3) L 4) L 5) L 6) L → Moderate risk of bias

			Coefficient → ranking method		
Johansson et al., 2016 [37]	1390 fairly healthy community-dwelling older adults aged 70 years (684 F; MMSE: F → 28.5 ± 1.6 vs. M → 28.3 ± 1.7; no significant differences between F and M when objectively measured 7-day total physical activity): over 1350 → 148 fallers (88 F); Inclusion criteria: sample representing the general population→ residence in the Umea municipal area and age of exactly 70 years-old at the time of testing.	**Prospective** study; Self-reported fall data by telephone 6 and 12 months after examination; → Fallers = (# of falls ≥ 1); Definition of an incident low-energy fall: "unexpected event in which participants came to rest on the ground" [28].	Motor task: **walking** 8.6 m at preferred pace (+ 1 m ahead of the walkway) (+ walking at fast speed only under ST condition) Concurrent cognitive task: **mental tracking/working memory task:** counting backward from 100 in increments of 1 Independent variables & analysis: in ST and DT, CoV for: step/stride width, step/stride length, step/stride time, stance time, swing time, stride velocity, double support time; Student's t-tests, multiple logistic regression models	**(1) Yes, (2) Yes & (3) Yes:** During the normal-speed trial, no differences in gait variability were detected between fallers and non-fallers, whereas **step width, step length, step time and stance time variability** were significantly **greater** in fallers **during the fast-speed trial** (p = 0.01, 0.02, 0.03 and 0.01, respectively). Nevertheless, **during DT**, fallers exhibited significantly **increased variability for step width, step length, stride length, step time, stance time, stride time, stride velocity and swing time** in comparison with non-fallers (p = 0.002, 0.004, 0.01, 0.005, 0.02, 0.02, 0.002 and 0.007, respectively). Moreover, in an adjusted logistic regression model (covariates: sex, physical activity, education level, smoking, cardiovascular disease, diabetes, MMSE, gait speed), **step width variance from the DT trial** represented an **independent predictor** of incident falls (OR = 1.09, 95% CI = 1.02-1.17, p = 0.01), **as well as other gait parameters under DT**. Limitations: limited generalization of the findings to other age groups, potential familiarization with the gait measurement system, difficulties of asking to recall falls.	1) M (no demographic characteristics directly related to fallers and non-fallers, but to females and males, and poor inclusion and exclusion criteria, even if population's description was quite exhaustive) 2) L 3) L 4) L 5) L 6) L → Low risk of bias
Pelosin et al., 2016 [55]	31 older adults: 17 fallers (73.4 ± 4.2 y., 10 F, MoCA score: 26.4 ± 1.6) and 14 age-matched non-fallers (72.1 ± 4.9 y., 5 F, MoCA: 28.3 ± 2); Inclusion criteria: age between 60 and 85 years, ability to walk for 5 min unassisted; Exclusion criteria: clinical diagnosis of dementia or other severe cognitive impairment (MMSE < 24), psychiatric co-morbidity, history of stroke or other neurologic disorders.	Cross-sectional (**retrospective**) study; Self-reported falls over the previous 6 months; → Fallers = (# of falls ≥ 2).	Motor task: **walking** in a corridor at a comfortable speed for 1 min Concurrent cognitive task: **verbal fluency task**: talking Independent variables & analysis: for ST, DT and proportionate difference (DTC in %): gait speed; repeated measures ANOVA with group as between-subjects factor and task (ST and DT) as within-subject factor + post-hoc t-tests with Bonferroni correction for multiple comparisons	**(1) Yes, (2) Not addressed & (3) Not addressed:** **Gait speed** was significantly **lower** in fallers than in non-fallers **during ST and DT** (p = 0.003 and 0.005). Unlike non-fallers, fallers significantly **reduced their gait speed under DT gait with respect to normal gait** (p = 0.022). Limitations: cholinergic activity was evaluated at rest (sitting position) and SAI is reduced in muscles involved in a specific motor task during movement, no plan to test whether anticholinergic drugs may improve cholinergic activity in the faller population.	1) L 2) L 3) M (no clear description of the concurrent cognitive task) 4) M (no formal definition of falls) 5) L 6) L → Moderate risk of bias
Freire Júnior et al., 2017 [22]	62 community-dwelling older adults: 27 fallers (67.96 ± 5.7 y.; 26 F; MMSE: 25, 95% CI 23.5-26.5; BESTest: 84.07 ± 9.43) and 35 non-fallers (67.97 ± 4.82 y.; 24 F; MMSE: 26.57, 95% CI 25.63-27.52; BESTest: 88.77 ± 7);	**Retrospective** study; Questionnaire about the history of falls in the 6 months preceding the assessment day; → Fallers = (# of falls = 1); Definition of a fall: [28].	Motor task: **walking** 8 m at self-selected speed (+ 1 m before the electronic carpet and 1 m after) Concurrent tasks: - **verbal fluency task:** naming animals without repeating names - **motor task:** transferring a coin from one pocket	**(1) No, (2) Not addressed & (3) Not addressed:** There were significant effects of the task (increased stride time and reduced gait speed, cadence and single support time under both DT conditions compared to ST, **decreased step length under both DT conditions compared to ST but with a larger reduction for CT, increased stride time variability in CT compared to MT and ST**), but **neither significant main effects of the faller status nor significant interaction effects between group and walking condition**.	1) M (exclusion criteria missed neurological diseases) 2) L 3) L 4) L 5) M (no covariates

	Exclusion criteria: inability to walk without help from others, severe impairment of balance, presence of cognitive impairment identified by MMSE (exclusion if MMSE score: ≤ 13 for illiterate elderly, ≤ 18 for people with 1-7 years of education, ≤ 26 for people with 8 years or more of education).		to the other Instructions: "do not prioritize either task" Independent variables & analysis: for ST, DT and proportionate DTC ($([DT_{walking} - ST_{walking}]/ST_{walking}) \times 100$): gait speed, cadence, stride time, step length, single support time, stride time CoV; 2-way repeated-measure ANOVAs (group as between-subjects factor and task as repeated measure, Bonferroni post-hoc tests); Mann-Whitney tests or independent Student's t-tests for comparing DTC between groups	Regarding **DTC**, no significant differences between groups were observed, whereas **significant differences in step length** were found between tasks: **CT > MT**, p = 0.0003 in **non-fallers** and 0.036 in **fallers** (the **same for stride time variability in non-fallers**, p = 0.016). Limitations: fallers had experienced only one fall over the past 6 months, performance on the concurrent cognitive and motor tasks were not measured → no information concerning strategy of task prioritization that might discriminate fallers from non-fallers.	taken in to account in the statistical analyses) 6) L → Moderate risk of bias
Verghese et al., 2017 [73]	166 high-functioning older adults (74.5 ± 6.07 y.; 85 F; RBANS: 91.56 ± 12): 71 fallers (34 with # of falls > 1) and 85 non-fallers; Inclusion criteria: community-residing adults, aged 65 years-old and older; Exclusion criteria: presence of dementia, inability to walk, active neurologic or psychiatric disorders severe enough to interfere with study assessments, presence of major visual or hearing loss, recent or planned surgical procedures restricting walking, disability, need for assistance or assistive devices to walk, presence of clinical gait abnormalities.	**Prospective** cohort study; 50-month follow-up period (mean follow-up: 33.9 ± 11.9 months), annual interviews based on a standardized questionnaire during in-person visits and phone calls every 2 to 3 months; Definition of a fall: "unintentionally coming down on the floor or to a lower level not as a result of a major intrinsic or extrinsic event" [39].	Motor task: **walking** at normal pace on an electronic walkway (for 3 continuous loops consisting of 6 straight segments and 5 turns) Concurrent cognitive task: **mental tracking/working memory task:** recitation of alternate letters of the alphabet (under ST: for 30 seconds while standing) Instructions: "to pay equal attention to both tasks to minimize task prioritization" Independent variables & analysis: gait stride velocity, correct letter rate per minute; Andersen-Gil extension of the Cox model (hazard ratios), adjusted for age, sex, education, comorbidity count, RBANS score, HbO_2 levels during normal walking and cognitive ST conditions, Digit Symbol Substitution test score, walking velocity and correct letter rate during DT (+ models where subjects with slow gait, with instrumental activity limitations, with fall history before baseline were excluded)	**(1) Not addressed, (2) Yes & (3) Yes:** **Higher PFC activation levels on fNIRS during DT predicted falls** (HR = 1.32, 95% CI = 1.01-1.7) and this association remained significant when controlling for all the covariates. However, PFC activation during both motor and cognitive ST, as well as gait velocity and letter rate during DT were not significantly associated with risk of falls. Limitations: focus limited to PFC analysis, very mild clinical signs and possibility that this compensatory brain activity do not occur in later clinical stages (associated with gait abnormalities), negotiating turns might be more cognitively demanding, observational study does not allow to report real causality.	1) M (no demographic characteristics directly related to fallers and non-fallers) 2) L 3) L 4) L 5) L 6) M (no p-values reported) → Moderate risk of bias
Caetano et al., 2018 [13]	50 healthy community-dwelling older adults: high-risk of falling group (n=22; 77 ± 8 y.; 16 F) and low-risk of falling group (n=28; 72 ± 4 y.; 18 F); Inclusion criteria: aged 65	**Retrospective** study; Classification as fallers and non-fallers based on falls experienced in the past 12 months and on the PPA	Motor task: gait adaptability test (GAT) → **walking** over a 6-m path at self-selected speed under 4 conditions: while avoiding an obstacle, stepping onto close or far targets, or walking without any stimulus on the pathway	**(1) Yes, (2) Yes & (3) No:** In adjusted logistic regression models, **at least one stepping error in the single GAT and reduced GAT velocity in both ST and DT conditions** were found to **discriminate** low- from high-risk of falling groups (χ^2 = 5.966, p = 0.015; t_{48} = 3.552, p = 0.001; t_{48} = 3.88, p < 0.001) and to be **independent predictors of high risk of falling**.	1) H (no reporting of a global cognitive score, even if dementia was an exclusion criterion) 2) L 3) L

	years-old and older, living independently in the community, cognitive ability to follow instructions, relatively healthy; Exclusion criteria: dementia, acute or terminate illness, progressive neurodegenerative diseases, major psychiatric illnesses, color-blindness or untreatable visual impairment, inability to walk independently, recent surgery affecting mobility.	score; → High fall-risk group = (history of multiple falls and/or PPA score ≥ 1.5); Definition of a fall: [41].	Concurrent cognitive task: **mental tracking/working memory task:** serial-3 subtraction from a two-digit number Independent variables & analysis: GAT errors, velocity of the stride preceding the target/obstacle; independent sample t-tests, Mann-Whitney-U tests or Chi-square tests + binary logistic regression (with covariates such as TMT, IconFES, quadriceps strength and age) + AUC of ROC curves	The **association between ST GAT errors and fall risk** (OR 3.54, 95% CI 0.67-18.65) was **mediated by impaired EF**, while the **association between GAT velocity and fall risk in ST** (OR = 1.69, 95% CI = 0.62-4.62) **and DT** (OR = 2.01, 95% CI = 0.75-5.37) situations was **mediated by high concern about falling, weak quadriceps strength and impaired EF**. However, **GAT under DT condition did not provide greater predictive power of fall risk over ST GAT** (χ^2 = 0.09, p = 0.76, for ROC curves comparison). Limitations: GAT might be perceived as a DT in itself, the performance of the cognitive task was not measured → no information about strategy of task prioritization that might discriminate fallers from non-fallers, retrospective aspect of the study.	4) L 5) L 6) L → Moderate risk of bias
Callisaya et al., 2018 [15]	424 older adults (77.8 ± 6.4 y.; 234 F; RBANS: 93.5 ± 12.6; mean normal gait speed: 98.3 ± 23 cm/s); Inclusion criteria: aged 65 years-old and older, participation in the longitudinal Central Control of Mobility in Aging (CCMA) study; Exclusion criteria: dementia, inability to walk, severe neurological or psychiatric conditions, major visual or auditory loss, receiving hemodialysis, recent or planned surgery that would interfere with assessments or restrict walking.	**Retrospective** study; Participants were asked if they had fallen in the past year; → Fallers = (# of falls ≥ 1).	Motor task: **walking** on a computerized mat (457.2 cm long) at normal walking speed Concurrent cognitive task: **mental tracking/working memory task:** recitation of alternate letters of the alphabet starting with the letter 'A' Instructions: "to pay equal attention to both the walking and talking tasks to avoid task prioritization effects" Independent variables & analysis: ST and DT normal walking speed; Spearman's correlation coefficients related to relationships between mobility measures and prior falls + multivariable linear regression, adjusting for age and gender, between clinic-based mobility measure and each community risk factors (including prior falls) in separate models + final models including each significant mobility measures in the same model	**(1) Not addressed, (2) Yes & (3) No:** Prior falls were significantly correlated with ST normal walking speed (r = -0.19, p < 0.001), DT walking speed (r = -0.13, p < 0.01), maze delay (r = 0.12, p < 0.05), time for ascending stairs (r = 0.21, p < 0.001) and time for descending stairs (r = 0.16, p < 0.001). **In separate regression models**, falls in previous year were significantly associated with **slower DT walking speed** (OR = 0.99, 95% CI = 0.98-0.99, p < 0.5), **ascending** (OR = 1.49, 95% CI = 1.21-1.84, p < 0.05) **and descending stairs** (OR = 1.25, 95% CI = 1.07-1.45, p = 0.002). However, in the **final model**, only time for ascending stairs (OR = 1.33, 95% CI = 1.05-1.68, p = 0.02) remained significant, the pseudo R^2 for the model being 5 %, with ascending stairs contributing 81.7% of 5%. Limitations: no objective measurements of community performance, self-reported measures were subject to recall or reporting bias, cross-sectional study → inability to make causal inferences, other gait parameters to be included (e.g., gait variability), small explained variance for some outcomes.	1) M (no demographic characteristics directly related to fallers and non-fallers) 2) L 3) H (no formal definition of fall and, number of falls and subjects who had fallen were not reported) 4) L 5) L 6) M (no complete reporting of the statistical analyses) → Moderate risk of bias
Commandeur et al., 2018 [18]	42 community-dwelling older adults: 27 fallers (75.9 ± 3.3 y.; 19 F; MMSE: 28.5 ± 1.6) and 15 non-fallers (75.8 ± 3.4 y.; 6 F; MMSE: 28.5 ± 1.1); Exclusion criteria: physician-diagnosed dementia, recent	**Retrospective** study; Self-reported falls over the previous 12 months; → Fallers = (# of falls ≥ 1); Definition of a fall: "if the participant came to rest on a lower surface as a result	Motor task: **walking** there and back (10 ST and 10 DT walking passes) at a self-selected preferred speed along a 6.4 m instrumented walkway (+ 1.5 m prior to and beyond the end of the mat) Concurrent cognitive task: **mental tracking/working memory task:** serial-7	**(1) Not addressed, (2) Yes & (3) Not addressed:** Among the 11 measures kept after PCA, 5 gait measures were sufficient for retrospectively classifying fallers and non-fallers with 92.3% sensitivity, 66.7% specificity and a total model classification of 82.9%: stride time difference, stride width difference, stride length difference, stride width variability difference and stride velocity variability difference. **Larger stride length difference and stride time**	1) L 2) L 3) L 4) L 5) L 6) L

	major illness or a neurological, sensory, or mobility impairment that would impede participation, MMSE ≤ 24, non-fluent in English.	of a loss of balance".	subtraction aloud from a randomly generated three-digit number Independent variables & analysis: mean and variability (SD) of DT scores and DTC (difference scores between ST and DT gait trials) for variables included in 4 sub-domains: length, width, timing and velocity; remove of highly collinear and theoretically redundant measures within each domain + PCA + backward stepwise binary logistic regression + Hosmer-Lemeshow test	**difference significantly and uniquely contributed to the increase of fall risk** (p = 0.042 and 0.047, respectively, within the logistic regression model). These DTC gait measures outperformed traditional clinical tests of strength, mobility and balance, and physiological assessments. Limitations: retrospective study.	→ Low risk of bias
Halliday et al., 2018 [27]	27 older adults: 12 fallers (76.25 ± 3.19 y.; 8 F) and 15 non-fallers (75.93 ± 3.41 y.; 7 F); Inclusion criteria: healthy, living in the community; Exclusion criteria: self-report of a physician-diagnosed major medical illness with residual motor or sensory deficits (e.g., PD, stroke, heart disease, dementia, cancer, brain tumor), severe sensory impairment, drug or alcohol abuse, history of inpatient psychiatric treatment, significant cognitive impairment (MMSE< 24), English as a second language.	**Retrospective** study; Follow-up period: the two-years leading up to the first study visit; → Fallers = (# of falls ≥ 1); Definition of a fall: "any instance in which the participant came to rest involuntary on a lower surface (e.g., ground or floor).	Motor task: **walking** at self-selected, normal walking speed along a 6.4 m instrumented walkway (+ 1.5 m before and after the mat ended) → 10 passes * total recorded walking distance of about 6.1 m Concurrent cognitive task: **mental tracking/working memory task:** serial-7 subtraction from a given three-digit starting number Independent variables & analysis: mean and CoV: swing time, step length; Student's t-tests (measures of effect size) + logistic regression analysis	**(1) Yes, (2) Yes & (3) Yes:** **Mean step length, step length CoV and swing time CoV** were significantly **larger** in fallers compared to non-fallers **in DT** (t(23) = 1.95, 3.05 and 2.1, p < 0.05, < 0.01 and < 0.05, d = 0.758, 1.178 and 0.786, respectively), and not in ST. **Step length variability in DT** showed a **significant effect within the logistic regression model** (OR = 1.163, 90% CI = 1.019-1.328, p = 0.03, on tailed). Limitations: optical array limited to coverage of a portion of the frontal cortex, MSIT with fNIRS relatively unprecedented in the literature, relatively liberal definition of fall status, participants did not undergo clinical assessment for MCI, small sample size, retrospective study.	1) M (existing exclusion criterion MMSE < 24, but no reporting of MMSE scores or other measure of global cognitive functions) 2) L 3) L 4) L 5) L 6) M (no description of methodology concerning statistical analyses within a dedicated section) → Moderate risk of bias
Howcroft et al., 2018 [31,34]	75 community-dwelling older adults: 28 fallers (75 ± 8.2 y.; 14 F) and 47 non-fallers (75.3 ± 5.5 y.; 30 F); Inclusion criteria: aged 65 years-old and older, without a fall in the 6 months before evaluation, living in the community; Exclusion criteria: self-reported cognitive disorder, inability to walk for 6 min without an	**Prospective** study (and comparison with retrospective studies from the same group [32,33]); → Fallers = (# of falls ≥ 1 during the 6-month follow-up period); Definition of a fall: [68].	Motor task: **walking** 7.62 m Concurrent cognitive task: **verbal fluency task**: saying words starting with A, F or S Independent variables & analysis: as in [32,33]: gait velocities for ST and DT trials; temporal, impulse and COP path-related variables from measurements performed via pressure-sensing insoles; descriptive statistics, temporal features, FFT quartile, REOH and MLE as accelerometer-derived	**(1) Yes, (2) Yes & (3) No:** a) During both ST and DT, gait velocity was not shown to be significantly different between fallers and non-fallers. On the contrary, **for DT gait**, fallers had significantly **lower stance AP COP path CoV** (p = 0.046) **and AP FFT first quartile for the head accelerometer** (p = 0.011) compared to non-fallers, whereas, **during ST**, fallers showed significantly **lower ML FFT first quartile for the left shank accelerometer** (p = 0.045) as well as **lower superior maximum acceleration for the right shank accelerometer** (p = 0.041). Gait differences between fallers and non-fallers were dependent on retrospective or prospective faller identification → more interest of using data based on prospective fall occurrence to be part of a	1) H (no reporting of global cognitive function - even if self-reported cognitive disorder was an exclusion criterion - or potential neurological disorders, and no baseline comparison of demographic data between fallers and non-fallers)

	assistive device.		parameters; a) as in [32]; b) as in [33] + predictive accuracy of the top 10 ST and top 10 DT models → repeated random sampling	successful clinical fall risk assessment protocol compared to measures based on retrospective fall occurrence. b) Although the **best overall models were based on DT walking** (for the best one: accuracy = 57%, sensitivity = 43%, specificity = 65%), the **comparison between ST- and DT-gait-based models did not reveal a clearly superior gait assessment for fall-risk prediction** (similar accuracies for the top ST- and DT-gait-based models). Limitations: performance of cognitive task not measured → no information about task prioritization → potential masking of faller and non-faller gait differences, 7.62 m walking trial may be not enough reflective of everyday walking, larger number of variables in the analysis increases the potential Type 1 errors.	2) L 3) L 4) L 5) M (no covariates taken in to account in the statistical analyses) 6) L → Moderate risk of bias
Minet et al., 2018 [50]	322 older women: 117 fallers from the falls clinic, 99 fallers (79 [76-85] y.; MMSE: 27 [25-29]) and 106 non-fallers (80 [75-86] y.; MMSE: 28 [26-29]) from the community; Inclusion criteria: women, aged 65 years-old and older; Exclusion criteria: not mobile enough to transfer from bed to chair with or without help.	Observational case-control (**retrospective**) study; Self-reported questionnaire to assess falls history over 1 year; → Once only faller and recurrent fallers (> 1 fall); Definition of a fall: [41].	Motor task: 4-meter **walking** test at preferred walking speed Concurrent cognitive task: **mental tracking/working memory task:** serial-3 subtractions Independent variables & analysis: for ST and DT: gait speed; for differences between groups: 1-way ANOVAs or Kruskal-Wallis tests, and then post-hoc independent t-tests or Mann-Whitney tests	**(1) Yes, (2) Not addressed & (3) Not addressed:** **Under both ST and DT**, **gait speed** was significantly **slower** in fallers compared to non-fallers from the community ($p < 0.001$). However, gait speed was not significantly different between community-dwelling once only fallers and recurrent fallers. Limitations: self-reported falls questionnaires.	1) M (poor inclusion and exclusion criteria such as cognitive impairment and neurological diseases) 2) L 3) L 4) L 5) M (no covariates taken in to account in the statistical analyses) 6) L → Moderate risk of bias
Gillain et al., 2019b [24,25]	96 community-dwelling older adults: 35 fallers (69 [67-76] y.; 17 F; MoCA: 27 [26-29]; SPPB: 10 [9-11]) and 61 non-fallers (70 [67-74] y.; 31 F; MoCA: 28 [26-29]; SPPB: 11 [10-12]); Inclusion criteria: aged 65 years-old and older, living independently at home, ability to understand French and to provide written informed consent; Exclusion criteria: history of fall(s) in the previous year, use	Longitudinal (**prospective**), observational study; 2-year follow-up, using personal falls diaries and phone calls every 3 months; → Fallers = (# of falls ≥ 1); Definition of a fall: [41].	Motor task: **walking** at self-selected comfortable speed (+ walking at self-selected fast speed) Concurrent cognitive task: **mental tracking/working memory task:** serial-7 subtraction from 100 Independent variables & analysis: for both ST, DT, proportionate differences (DTC and fast walking improvement): gait speed, stride length, stride frequency, stride symmetry, stride regularity, and minimum toe clearance MTC (mean, median, minimum, SD, variance, CoV, delta1 = max - mean, delta2 = mean - min);	**(1) Yes, (2) Yes & (3) Inconclusive:** Compared to non-fallers, fallers had **lower gait speed during fast walking ST** ($p = 0.035$), **shorter stride length during normal speed and fast walking ST** ($p = 0.035$ and 0.01, respectively) and **higher symmetry DTC** ($p = 0.022$). Among the discriminative variables, **symmetry DTC** was **the only one significantly related to the risk of falls** (OR = 1.018, 95% CI = 1.002-1.033, $p = 0.027$). The obtained model included symmetry DTC, stride length in fast walking ST, stiffness, mean MTC in normal speed walking ST, MTC CoV DTC, MTC variance and mean MTC in fast walking ST, delta1 MTC in DT and gender. Regarding its performances, this model was related to an accuracy of 84%, a sensitivity of 80%, a specificity of 87%, a PPV of 78%, a NPV of 88%, an AUC related to ROC curve of 0.84, and an area	1) L 2) L 3) L 4) L 5) L 6) L → Low risk of bias

	of a walking aid, gait disorders and/or increased fall risk related to neurological or osteoarticular disease, dementia, hip or knee prosthesis in the previous year, pain when walking, acute respiratory or cardiac illness (< 6 months), recent hospitalization (< 3 months), untreated or uncontrolled comorbidities, use of neuroleptic and sedative drugs (except sleeping pills), and presence of a cardiac pacing device.		1-way ANOVAs or Kruskal-Wallis tests + binary logistic regression analysis + supervised machine learning algorithm (J48 classifier) → accuracy and sensitivity	under the Precision Recall Curve of 0.83. Limitations: small sample size, with non-fallers that were more numerous than fallers → it led to a first classification node of the model that identified non-fallers (because chosen as the attribute that allows the classification of higher number of people), while the aim of the present study was to identify fallers → the results obtained were limited by the volume of available data associated with prospective fall risk, as it was the case for the last classification node; no external validation of the classification model in an independent sample that was different from the one used to develop the model.	

D. Detailed Table of Results from the Systematic Literature Review About Dual Tasks Involving Gait Initiation

Table D.1 Articles about dual tasks involving gait initiation that were included in the systematic literature review. Abbreviations: y. = years; F = females; M = males; # = number; OR = odds ratio; RR = risk ratio; CI = confidence interval; MMSE = Minimal Mental State Examination; RDST = Rapid Dementia Screening Test; EF = executive function; RT = reaction time.

Authors	Population	Falls	Dual-task paradigm & discriminative/predictive analysis	(1) Do DT-related changes or DT performance discriminate fallers from non-fallers? (2) Are DT-related changes or DT performance predictors of falling? (3) Is the DT-related predictive strength superior compared to the ST-related one? (Yes/No/Inconclusive/Not addressed)	Risk of bias via QUIPS tool (High H, Moderate M, Low L risk of bias)
Callisaya et al., 2016 [14]	124 older adults: 27 single fallers (71.3 ± 5.3 y.; 13 F), 20 multiple fallers (73.5 ± 9 y.; 11 F) and 77 non-fallers (70.2 ± 6.6 y.; 29 F); Inclusion criteria: aged between 60-85 years-old, randomly selected from the Southern Tasmanian electoral roll; Exclusion criteria: resident of a nurse home, inability to walk without the use of gait aid, any contraindications to having an MRI scan, suffering from PD or dementia.	**Prospective** study; Falls questionnaire sent every 2 months for 12 months + falls calendar + follow-up with a phone call; → Fallers = (# of falls ≥ 1) (single fallers or multiple fallers); Definition of a fall: [41].	Motor task: **starting walking** in response to a buzzer activated at random times Concurrent cognitive task: **mental tracking/working memory task:** 3-serial subtraction Independent variables & analysis: time from stimulus to first lateral movement, transfer time (from first lateral movement to toe off of the leading foot), swing time (from toe off to foot contact), overall GI time form stimulus to leading foot contact; log multinomial regression with adjustment for age and sex, and then also for physiological and cognitive fall risk factors	**(1) Not addressed, (2) Yes & (3) No:** There was no association between GI time (or any of its components) and single falls over 12 months. **Slower overall GI time under ST and DT** (ST: RR = 1.28, 95% CI = 1.03-1.58; DT: RR = 1.14, 95% CI = 1.02-1.27), **swing time under DT** (RR = 1.44, 95% CI = 1.08-1.94) and **slower time to first lateral movement under ST** (RR = 1.9, 95% CI = 1.23-2.94) **increased the risk of multiple falls**. However, **GI under DT did not increase the discrimination of multiple fallers over ST condition**: slower time to first lateral movement under ST showed the strongest association with multiple falls. Limitations: performance of the concurrent cognitive task was not recorded, which did not provide any information concerning strategy of task prioritization and did not allow comparing sensitivity with other types of DT; heels spaced by 6 cm may have influenced stability for some subjects.	1) H (no global cognition score reported even if dementia was an exclusion criterion, and no statistical comparisons on demographic characteristics at baseline) 2) L 3) L 4) L 5) L 6) M (no p-values reported) → Moderate risk of bias

E. Detailed Table of Results from the Systematic Literature Review About Dual Tasks Involving Postural Control

Table E.1 Articles about dual tasks involving postural control that were included in the systematic literature review. Abbreviations: y. = years; F = females; M = males; # = number; IRR = incidence rate ratio; CI = confidence interval; MMSE = Minimal Mental State Examination; SPPB = Short Physical Performance Battery; POMA = Performance Oriented Mobility Assessment; BESTest = Balance Evaluation Systems Test; AP = anteroposterior; ML = mediolateral; PCA = Principal Component Analysis; RMS = root mean square; RT = reaction time.

Authors	Population	Falls	Dual-task paradigm & discriminative/predictive analysis	(1) Do DT-related changes or DT performance discriminate fallers from non-fallers? (2) Are DT-related changes or DT performance predictors of falling? (3) Is the DT-related predictive strength superior compared to the ST-related one? (Yes/No/Inconclusive/Not addressed)	Risk of bias via QUIPS tool (High H, Moderate M, Low L risk of bias)
Kang et al., 2013 [38]	717 relatively healthy community-dwelling older adults (77.9 ± 5.3 y.; 458 F; MMSE: 27.1 ± 2.6; 90 subjects with BBS ≤ 45): 131 outdoor fallers, 137 indoor fallers, 129 fallers with both outdoor and indoor falls and 320 non-fallers; Inclusion criteria: aged 70 years-old and older, from the Boston area, living in the community, ability to walk 6 m and to communicate in English; Exclusion criteria: cognitive impairment (MMSE ≤ 18), terminal disease, severe hearing or vision loss.	**Prospective** study; Falls monitored using a monthly mail-in calendar over 6-36 months and telephone interviews; → Fallers = (# of falls ≥ 1); Definition of a fall: [39]; Characterization into indoor (i.e., falls in one's own home, someone else's home, other buildings and other enclosed spaces like transportation vehicles) and outdoor falls (i.e., falls in outside stairs, gardens, yards, sidewalks, streets, curbs, parking lots, etc).	Motor task: **quiet standing** barefoot with eyes open for 30 s Concurrent cognitive task: **mental tracking/working memory task:** serial-3 subtraction from 500 (individual adaptation of the task in case of difficulty) Instructions: "to prioritize standing and look forward" Independent variables & analysis: In AP and ML directions, during ST and DT: COM RMS, postural stiffness, postural damping; negative binomial regression models, with the number of falls for a given period as dependent variable and model adjustments by the time spent either indoor or outdoor and clinical variables that were associated with both prospective falls and the biomechanical variable	**(1) Not addressed, (2) Yes & (3) No:** **Only AP COM RMS was significantly smaller in non-fallers** compared to fallers (p = 0.015). **Greater postural stiffness and damping were associated with lower outdoor fall risks**. Furthermore, **greater COM RMS was associated with higher indoor falls** (IRR ranges = 1.4-1.66, p < 0.05), whereas **greater damping in the AP direction was related to lower rates of indoor falls** (IRR = 0.65, 95% CI = 0.42-0.99, p = 0.044). Except for the last predictor, the associations of postural measures with indoor and outdoor fall rates were invariant by direction (AP vs. ML) and by condition (ST vs. DT). Therefore, **measuring postural control under DT did not improve fall prediction**. Limitations: lack of a feedback mechanism in the inverted pendulum model used, instruction of prioritization of the standing task while looking forward.	1) M (no demographic characteristics directly related to fallers and non-fallers, and a neurological disorder was not an exclusion criteria) 2) L 3) L 4) L 5) L 6) M (p-values and statistical variables are plotted but not all clearly reported) → Moderate risk of bias
Maranesi et al., 2015 [47]	130 older adults: 45 infrequent fallers (79 ± 6 y.; 26 F; MMSE: 25 ± 3; POMA, gait score = 11; POMA, balance score = 13), 18 frequent fallers (81 ± 6 y.; 16 F; MMSE: 25 ± 3; POMA, gait score = 10; POMA, balance score = 14) and 67 non-fallers	**Retrospective** study; Last year fall history; → Infrequent fallers = 1 or 2 falls, frequent fallers ≥ 2 falls.	Motor task: **quiet standing** with eyes open and closed on both a firm and a compliant surface during 30 s Concurrent cognitive task: **mental tracking/working memory task:** serial-7 subtraction (performed while standing with eyes open on a firm surface)	**(1) Yes but…, (2) Not addressed & (3) Not addressed:** **Postural DT on a firm surface** and related posturographic parameters (**RANGE-AP, MVELO-AP and MVELO-ML**) were significantly **different between non-fallers and frequent fallers**, while **RANGE-AP** was also found to be significantly **different between infrequent and frequent fallers**. **However, performing postural ST with eyes open on a compliant**	1) M (poor inclusion and exclusion criteria) 2) L 3) L 4) M (no formal definition of a fall) 5) M (covariates not

	(79 ± 5 y.; 38 F; MMSE: 26 ± 3; POMA, gait score = 11; POMA, balance score = 14); Inclusion criteria: cognitive ability; Exclusion criteria: diagnosed dementia.		Independent variables & analysis: MDIST-AP (mean distance-AP, average AP distance from the mean COP) , MDIST-ML, RDIST-AP (RMS distance-AP), RDIST-ML, RANGE-AP (maximum distance between 2 points of the AP time series), RANGE-ML, MVELO-AP (average velocity of the COP in the AP direction), MVELO-ML, AREA-SW (estimation of the area enclosed by the COP path per unit of time), MFREQ-AP (frequency of a sinusoidal oscillation with an average value of MDIST-AP and a total path length of total excursions-AP), MFREQ-ML, pfap-50 (frequency below which 50% of the power spectral density of the AP times series is found), pfml-50, pfap-95, pfml-95, MD (mean distance fixed radius = mean spatial distance between 2 consecutive peaks of the sway density curve calculated with relative radius), MP (mean duration of the peaks of the sway density curve calculated with relative radius); for group differences: Kruskal-Wallis tests and post-hoc comparisons with Wilcoxon Rank Sum tests + PCA for each task → Kruskal-Wallis test	**surface and using PCA-derived parameters allowed to discriminate between non-fallers and (infrequent and frequent) fallers and between infrequent fallers and frequent fallers.** Indeed, the parameter derived from the first principal component (PC1) was significantly different between all pairs of groups ($p < 0.01$). For this task, PC1 involved posturographic parameters concerning the AP variation in COP displacement: MDIST-AP, RDIST-AP, RANGE-AP. Limitations: retrospective study, acquisition of only a single trial for each test condition, use of only one force platform instead of two.	taken in to account in the statistical analyses) 6) M (no reporting of exact p-values) → Moderate risk of bias
Westlake et al., 2016 [74]	23 older adults: 12 fallers (70 ± 5 y.; MMSE = 29) and 11 non-fallers (69 ± 4 y.; MMSE = 30); Exclusion criteria: significant musculoskeletal, vestibular or neurological impairments, MMSE score < 24 (suggestive of dementia).	**Retrospective** study; Falls history over the last year; → Fallers = (# of falls ≥ 1); Definition of a fall: [39].	Motor task: maintaining **postural stability** under 2 different perturbation conditions ("quickly grab one handrail and do not take a step"): predictable and unpredictable Concurrent cognitive tasks: - **verbal fluency task:** associated verb generation as quickly as possible after having heard a noun that was read by a staff member - **mental tracking/working memory task:** 1-back verb generation task Instructions: "not to prioritize one task over the other (i.e., balance vs. cognitive) once the perturbation occurred" Independent variables & analysis: RT (time from the onset of platform perturbation to initial arm response), movement time (time from initial arm response to handrail contact), grasp error frequency, direction of grasp, errors in verb	**(1) Yes, (2) Not addressed & (3) Not addressed:** The only significant difference between older adult fallers and non-fallers concerned **grasp errors under both DT conditions**, with a **higher amount of errors** in fallers compared to non-fallers (verb generation: $t(21) = 9.31$, $p = 0.03$; 1-back verb generation: $t(21) = 9.64$, $p = 0.013$). A longer movement time under both DT conditions was observed in fallers in comparison with non-fallers, but this difference was not significant. Limitations: retrospective fall data, only a lateral reach response induced from stationary standing while perturbations occur from multiple directions during dynamic walking.	1) M (some missing information like gender, and no statistical comparisons on demographic characteristics at baseline) 2) L 3) L 4) L 5) M (covariates not taken in to account in the statistical analyses) 6) L → Moderate risk of bias

			generation; 2-way (3 groups x 4 conditions) repeated measures ANOVA with condition as the repeated factor and Tukey-Kramer post-hoc tests, or Kruskal-Wallis tests and Dunn's multiple comparison post-hoc tests		
Rinaldi et al., 2017 [59,60]	30 older adults: 15 fallers (70.1 ± 5.1 y.; 15 F; MMSE: 27 ± 3.2; Mini-BESTest: 19 ± 2.6) and 15 non-fallers (71.8 ± 5.8 y.; 15 F; MMSE: 28 ± 1.3; Mini-BESTest: 27.3 ± 1.6); Inclusion criteria: right-handed, normal or corrected-to-normal vision, no neurological /musculoskeletal disorder that would affect task performance; Exclusion criteria: cognitive impairment (MMSE < 24), ability to walk without assistance.	**Retrospective** study; 12-month follow-up period prior to data collection; → Fallers = (# of falls ≥ 1); Definition of a fall: [39].	Motor task: **walking** at self-selected speed (also perform as ST) (or **postural control:** performing the concurrent task while staying stationary → in [60]) Concurrent task: **motor task**: to reach and grasp a dowel with the right hand and without contacting the obstacles and knocking down the support, under different difficulty levels: stable (SB) and unstable (UB) bases without obstacles, stable base with obstacles at short (SSD) and long (SLD) distances, and unstable base with obstacles at short (USD) and long (ULD) distances Instructions: "to walk at their self-selected speed and to continue walking when grasping the dowel" Independent variables & analysis: frequency of occurrence of: different joint couplings: right-left shoulder and right shoulder-right hip, different movement directions: flexion/extension and adduction/abduction, different patterns of coordination: in-phase, anti-phase, left and right shoulder phase and right hip phase; for group differences: 1-way ANOVAs + repeated measures 3-way ANOVAs (groups x conditions [grasping conditions or ST versus DT] x strides [stride at the moment of dowel contact and one stride before contact]) + ANCOVA for differences in gait phases (double or single support, ipsilateral or contralateral) used according to grasping difficulty, with walking speed as covariate + post-hoc tests with Bonferroni adjustments	**(1) Yes, (2) Not addressed & (3) Not addressed:** In a previous study from the group using the same dataset but other sort of analyses [60], **step width** (p = 0.003) **and step duration** (p = 0.03) were **greater** in fallers than in non-fallers. Furthermore, **step velocity** was **lower** in fallers compared to non-fallers, **in step at dowel contact** (p ≤ 0.0001). Moreover, fallers exhibited a **greater reduction in AP COM velocity** than non-fallers (p ≤ 0.0001), while they presented a **minimum AP COM velocity significantly earlier** than non-fallers **before dowel contact** (p = 0.004). **AP and ML margins of dynamic stability** were **greater** for fallers than for non-fallers (p = 0.022 and ≤ 0.001, respectively). Finally, concerning the prehension task, in comparison with non-fallers, fallers showed a **greater movement time** (p = 0.046) **and temporal difference between right heel contact and reaching onset** (p = 0.002), and **lower peak wrist velocity** (p = 0.0001), **time-to-peak grip aperture** (p = 0.002) only **during walking DT**, **peak grip aperture velocity during postural DT** (p = 0.042) and **time-to-peak grip aperture velocity** (p = 0.007).→ **Generalized slowing down in movement performance in fallers.** Here (in [59]), **mean walking speed during both ST and DT** was significantly **lower** in fallers compared to non-fallers (p = 0.014 and 0.001, respectively). Fallers presented a **higher frequency of grasping the dowel in double support** in comparison with non-fallers, whereas **non-fallers** showed a **greater frequency of dowel grasping using a contralateral single support.→ Greater decoupling between walking and prehension in fallers.** Limitations: level of difficulty of the manual task potentially not high enough to elicit modifications in interlimb coordination, subjects that were free to choose their walking speed.	1) L 2) L 3) L 4) L 5) L 6) M (all the p-values related to post-hoc tests were not clearly reported) → Low risk of bias
Zhou et al., 2017 [79]	738 older adults: 460 fallers (78.1 ± 5.5 y.; 292 F; SPPB: 9.3 ± 2.6) and 278 non-fallers (77.9 ± 5.3 y.; 178 F; SPPB: 9.4 ± 2.4); Inclusion criteria: aged 70	**Prospective** study; Over a follow-up period of 48 months using monthly falls calendar and follow-up interviews;	Motor task: **quiet standing** barefoot with eyes open for 30 s Concurrent cognitive task: **mental tracking/working memory task:** serial-3	**(1) Yes, (2) Yes & (3) Yes:** Fallers exhibited **lower AP postural sway complexity** (measured by multiscale entropy) **under both ST and DT** in comparison with non-fallers (p = 0.007 and 0.002, respectively), while there were no differences in terms of sway speed, sway area, AP path length and	1) H (existing exclusion criterion MMSE ≤ 18, but no reporting of MMSE scores or other

	years-old and older, ability to walk 6 m without personal assistance (walking aids permitted); Exclusion criteria: cognitive impairment (MMSE ≤ 18), terminal disease, severe hearing or vision loss.	→ Fallers = (# of falls ≥ 1); Definition of a fall: "unintentionally coming to rest on the ground or other lower level, not as a result of an overwhelming external hazard or a major intrinsic event".	subtraction from 500 (individual adaptation of the task in case of difficulty) Independent variables & analysis: AP postural sway complexity metric, sway speed, sway area, AP path length; for differences between fallers and non-fallers as well as between quintiles of the continuous postural sway complexity: ANOVAs and Student's t-tests + negative binomial regression with involvement of covariates → IRR	SPPB score. In negative binomial analyses with covariate adjustments**, AP complexity of postural sway during ST and DT was independently negatively associated with the incidence of future falls** (ST: IRR = 0.98, 95% CI = 0.96-0.99, p = 0.02; DT: IRR = 0.98, 95% CI: 0.97-0.99, p = 0.02). Unlikely, sway speed, sway area, AP path length and SPPB score did not significantly predict future falls rate. **During ST**, older adults in the **quintile 1** had a significantly **higher falls rate than those in quintiles 4 and 5** (p < 0.01), whereas, **during DT**, those in **quintiles 1,2 and 3 of complexity presented higher fall rates than those in quintiles 4 and 5** (p < 0.04). **In the DT condition**, older adults in the **lower quintiles of complexity (quintiles 1, 2 and 3) experienced significantly more falls during the follow-up** (IRRs = 1.48, 1.42 and 1.44, 95% CI = 1.04-1.99, p < 0.03) **compared to those in the highest quintile of complexity (quintile 5)**. **DT postural sway complexity**, with its particular sensitivity, was a **better predictor of future falls risk than ST postural sway complexity**. Limitations: postural sway complexity only analyzed in AP direction.	measure of global cognitive functions, and no exclusion criterion such as neurological disease) 2) L 3) L 4) L 5) L 6) L → Moderate risk of bias
Santos et al., 2018 [61]	30 older women: 15 fallers (79 ± 6 y.; 26 F; MMSE : 25 ± 3; POMA, gait score = 11; POMA, balance score = 13) and 15 non-fallers (81 ± 6 y.; 16 F; MMSE : 25 ± 3; POMA, gait score = 10; POMA, balance score = 14) ; Inclusion criteria: 65 years-old and older, ability to walk without the help of others or walking aids, (gender was not an inclusion criterion); Exclusion criteria: visual impairments not corrected by eyeglasses or contact lenses, severe neuromuscular, musculoskeletal or cardiopulmonary disorders, dysfunction of the dominant upper limb, low cognition (MMSE < 24).	**Retrospective** study; 6-month follow-up period; → Fallers = (# of falls ≥ 1).	Motor task: **walking** (also perform as ST) or **postural control** (performing the concurrent task while staying stationary) Concurrent task: **manual task**: grasping, transporting and placing the dowel as close as possible to the center of the target, with 4 different levels of difficulty according to target distance (short versus long distance) and target size (target of either 8 or 12 cm) Independent variables & analysis: variables related to the analysis of dowel position relative to target center: radial error, constant error (target center position - dowel center) in AP and ML directions; variables related to the analysis of dowel transport: duration of transport, peak wrist velocity during dowel transport, time to peak wrist velocity adjusted to the duration of transport; variables related to gait analysis: AP and ML margin of dynamic stability at dowel contact and release; Student's t tests for independent samples + for dowel position and transport: 4-way (group x task x distance x diameter) ANOVAs with repeated measures; for gait variables: 2 4-way (group x task x	**(1) Yes, (2) Not addressed & (3) Not addressed:** **During ST walking**, **step length** was significantly **smaller** in fallers compared to non-fallers (p = 0.004). Addition of a manual task did not affect gait stability of fallers but they underperformed in this manual task of grasping, transporting and placing a dowel. Indeed, fallers were **less accurate** (significantly **larger AP constant error**, particularly **for the walking DT combined with the 8-cm target**; F(1,28) = 6.395, p = 0.017) and **slower** (**during the postural DT and for the long distance** in comparison with the walking DT and short distance, respectively; p ≤ 0.0001) **in the dowel-positioning task** than were non-fallers. Limitations: sample composed only of women, task that is not as close to everyday activities as others could be, force applied on the dowel not quantified, different simple manual tasks not assessed.	1) M (only women) 2) L 3) L 4) M (no formal definition of a fall) 5) M (covariates not taken in to account in the statistical analyses) 6) L → Moderate risk of bias

			distance x diameter) MANOVAs with repeated measures + post-hoc analysis with Bonferroni adjustment		
Uiga et al., 2018 [70]	78 older adults: 34 fallers (69 ± 3.52 y.; 29 F; MMSE: 29.03 ± 0.98) and 36 non-fallers (68.89 ± 3.7 y.; 28 F; MMSE: 29.23 ± 1.11); Exclusion criteria: physical or neurological impairment, static visual acuity worse than 20/40, use of walking aids, Cantonese version of MMSE < 24/30 that would not reflect normal cognition.	**Retrospective** study; Falls history over the last 2 years; → Fallers = (# of falls ≥ 1); Definition of a fall: "any fall for which a participant was clearly able to identify a timeframe, venue and mechanism".	Motor task: 1-minute **quiet standing** Concurrent cognitive task: **discrimination and decision-making task:** tone-counting task → monitoring and subsequently reporting the number of high-pitched tones presented via computer speakers Instructions: "to prioritize the balancing task" Independent variables & analysis: COP measures of postural stability: ellipsoidal area (85.35%), average velocity, SD of ML axis (SD-ML), SD-AP, ML sample entropy (SampEn-ML), SampEn-AP, ML detrended fluctuation analysis (DFA-ML), DFA-AP, tone-counting accuracy; for group differences: 2 (task) x 3 (group, which also included a group of young adults) multivariate repeated measures ANOVAs separately for traditional COP variables and for complexity-based COP variables + univariate ANOVA for group differences in tone-counting accuracy + Bonferroni corrected pairwise comparisons	**(1) Yes, (2) Not addressed & (3) Not addressed:** Regarding traditional COP sway variables, there was a significant effect of group on balance performance ($F(8.228) = 4.02$, $p < 0.001$), with **greater area of sway** ($p < 0.001$), **SD-ML** ($p = 0.006$) **and SD-AP** ($p = 0.007$) in fallers compared to non-fallers. Particularly, under DT condition, group difference was particularly significant for area of sway. A significant effect of task condition on balance performance was also found ($F(4,114) = 4.06$, $p = 0.004$), with less average sway velocity ($p < 0.001$) and less SD-AP ($p = 0.043$) under DT in comparison with ST. However, **no significant interaction between task condition and group** was observed. Concerning complexity-based COP sway variables, there was no significant group effect (older adults fallers versus non-fallers) on such kind of variables, a significant effect of task condition but with non-significant results to post-hoc tests, and no interaction between group and task condition. Moreover, no significant difference between older adult fallers and non-fallers was found for mean tone-counting accuracy. Limitations: quiet standing is a relatively easy task, healthy and active older adults → lack of generalization in the old population.	1) M (no statistical comparisons on demographic characteristics at baseline) 2) L 3) L 4) L 5) L 6) L → Low risk of bias

F. Detailed Table of Results from the Systematic Literature Review About Dual Tasks Involving Turns

Table F.1 Articles about dual tasks involving turns that were included in the systematic literature review. Abbreviations: y. = years; F = females; M = males; # = number; OR = odds ratio; CI = confidence interval; MMSE = Minimal Mental State Examination; POMA = Performance Oriented Mobility Assessment; RDST = Rapid Dementia Screening Test; AUC = Area Under the Curve.

Authors	Population	Falls	Dual-task paradigm & discriminative/predictive analysis	(1) Do DT-related changes or DT performance discriminate fallers from non-fallers? (2) Are DT-related changes or DT performance predictors of falling? (3) Is the DT-related predictive strength superior compared to the ST-related one? (Yes/No/Inconclusive/Not addressed)	Risk of bias via QUIPS tool (High H, Moderate M, Low L risk of bias)
Muhaidat et al., 2014 [52]	62 independently ambulant community-dwelling older adults: 13 fallers (82 ± 12 y.; 9 F; MMSE: 29 ± 3; POMA: 26 ± 7) and 49 non-fallers (75 ± 11.5 y.; 32 F; MMSE: 29 ± 2; POMA: 28 ± 2); Inclusion criteria: aged 65 years-old and older, living in the community, able to speak and understand English, able to travel to the assessment laboratory, MMSE ≥ 24, able to maintain their feet together and adopt the semi-tandem stance of the 4-test balance scale for 10 s Exclusion criteria: use of walking frames and uncorrected visual or hearing impairments.	**Prospective** study; 6-month follow-up validation cohort study, with monthly falls' diaries and telephone interviews; → Fallers = (# of falls ≥ 1); + falls in the previous year.	8 dual-task tests and 1 triple-task test, with **straight walking with or without obstacles**, **walking with turns** and **stair descent** as motor tasks and **motor**, **verbal fluency, mental tracking/working memory**, and **discrimination and decision-making tasks** as concurrent tasks: - straight walking and visuospatial clock task; - walking with turns and naming animals; - walking with turns and counting backwards in 3s; - avoiding stationary obstacles and naming animals; - avoiding a moving obstacle and carrying a cup; - timed Up & Go (TUG) and carrying a cup; - stair descent and naming animals; - walking while talking complex; - straight walking, visuospatial clock task, and carrying a cup Instructions: "to walk at their preferred speed and to perform both tasks as well as they could" Independent variables & analysis: for ST, DT, proportionate and absolute differences: walking time, performance speed (total answers/second), accuracy (errors/total answers); random forest classification analysis (mean decrease in accuracy, mean decrease in Gini impurity, out-of-bag error rate) + binary logistic regression for the top 5 variables	**(1) Not addressed, (2) Yes & (3) Inconclusive**: 18 (36.7%) of the non-fallers and 10 (76.9%) of the fallers had an history of falls in the previous year (p = 0.01). This multivariate analysis **failed to identify a useful predictive tool**, but gave an indication regarding **the most useful variables in predicting falls in a multivariate analysis**; that is, **time for avoiding a moving obstacle in ST and DT while carrying a cup, time required to perform the walking task in the triple-task test, time for TUG in DT, and absolute difference for TUG time between ST and DT**. **For these 5 variables**, the **ORs** obtained with binary logistic regression were all **statistically significant** (OR = 1.29, 1.22, 1.12, 1.23, 0.61; 95% CI = 1.11-1.54, 1.07-1.41, 1.03-1.24, 1.1-1.41, 0.43-0. 81; p = 0.002, 0.004, 0.01, 0.001, 0.002). Moreover, in terms of the form of DT outcomes, absolute difference could be a better predictor of falls than the proportionate difference. Limitations: small sample size while large number of variables, short follow-up period, and participation of subjects in exercise classes.	1) M (no information regarding comorbidities; e.g., a neurological disorder) 2) L 3) L 4) M (no formal definition of a fall) 5) L 6) L → Moderate risk of bias

Ansai et al., 2016 [1]	67 community-dwelling older adults: 24 fallers (80-85 y.; 18 F; MMSE = 24) and 43 non-fallers (80-83 y.; 27 F; MMSE = 27); Inclusion criteria: aged 80 years-old and older, living in the community (non-institutionalized), sedentary, ability to walk alone either with or without a cane; Exclusion criteria: walking with a walker, cognitive, neurological and skeletal muscle disorders that prevent walking correctly, MMSE score below the designated educational level cut-off minus one standard deviation.	Cross-sectional (**retrospective**) study; Self-report of falls over the past 3 months; → Fallers = (# of falls ≥ 1); Definition of a fall: "an event which results in a person coming to rest inadvertently on the ground or floor or other lower level and other than as a consequence of the following: sustaining a violent blow; loss of consciousness; sudden onset of paralysis; or an epileptic seizure" [16].	Motor task: **TUG** test (**walking, turning and transfers**) Concurrent tasks: - **mental tracking task/working memory task:** repeating days of the week in reverse order; - **motor task:** grasping a drinking filled with water Independent variables & analysis: for both cognitive and motor DT-TUG tests: completion time, number of steps, occurrence of poured water, number of correct and incorrect answers, number of correct answers to time spent ratio, number of total answers to time spent ratio; Spearman product-moment correlation coefficient + Mann-Whitney tests or Chi-square tests	**(1) Yes, (2) Not addressed & (3) Not addressed:** Most balance and DT variables were significantly correlated. While fallers did not show differences on balance tests in comparison with non-fallers, they **took significantly more time and steps during both TUG tests with cognitive** (p = 0.013 and 0.057, respectively) **or motor concurrent task** (p = 0.037 and 0.039). Limitations: small sample size, absence of a random sampling, non-prospective analysis of falls, lack of certain gait variables such as step variability.	1) L 2) L 3) L 4) L 5) L 6) L → Low risk of bias
Ponti et al., 2017 [56]	36 community-dwelling healthy older adults: 18 fallers (75.25 ± 8.2 y.; 15 F; MMSE: 23.75 ± 3.93) and 18 non-fallers (70.94 ± 6.69 y.; 10 F; MMSE: 26.46 ± 4.35); Inclusion criteria: aged 60 years-old and older, ability to stand up from a chair with arms without other person's help and to walk independently without aid device, eutrophic; Exclusion criteria: amputation and/or use of lower limb prosthesis or other device that modifies the gait pattern, neurological or muscular disease, any condition listed it Charlson Comorbidity Index, obesity, presence of any important risk factor that compromises safety, according to the evaluator.	**Retrospective** study; Participants questioned about their history of falls over the past year; Definition of a fall: "come to inadvertently get in the soil or in other lower level, excluding intentional position changes to lean on furniture, walls or other objects" [76].	Motor task: **TUG** test Concurrent tasks: - **motor task**: carrying a cup filled with water (TUG-M) - **mental tracking/working memory task**: continuous simple subtraction questions (TUG-C) Independent variables & analysis: completion time, mean completion time among tasks, number of steps; for the whole signal (containing the 3 TUG tasks), TUG ST, TUG-M and TUG-C: Power Spectral Entropy (PSE), Power Spectrum Peak Frequency (PSPF), Power Spectrum Peak (PSP), Weighted Power Spectrum Peak (WPSP); distance-based features, features fusion; t-tests for group comparisons on traditional TUG parameters + Mann-Whitney U-tests for group comparisons on frequency domain features, and fusion of relevant features + ROC analysis (sensitivity, specificity, AUC, f1-Score)	**(1) Yes, (2) Yes & (3) Yes:** Traditional features such as (mean) completion time and number of steps were not significantly different between fallers and non-fallers in any of the versions of TUG test (ST and both DT). Regarding frequency domain features, only **lower PSE** (p = 0.014), **WPSP2** (p = 0.022) **and WPSP3** (p = 0.009) **related to TUG-C** as well as **lower features fusion** (p = 0.001), **lower PSE** (p = 0.029) **and PSP** (p = 0.014) **differences between the whole signal and the TUG-C**, **lower PSPF difference between TUG and TUG-M** (p = 0.049), and **lower WPSP difference between TUG-M and TUG-C** (p = 0.034) as well as **lower distances fusion** (p = 0.001) were significantly **able to identify fallers from non-fallers**. Outcomes from the ROC analysis were consistent with the previously reported results: **the extracted frequency and distance-based features had higher values of AUC, f1-Scores, sensitivity and specificity compared to the traditional parameters** (e.g., completion times) **related to TUG tests**. However, the **best results were allocated to the fusion of distance-based features**, with AUC = 0.84, f1-Score = 0.83, sensitivity = specificity = 0.83 for the probability cut-off point 0.5 with a 95% CI 0.62-0.91. Therefore, both distance-based features and fusion have shown to be interesting methods to improve the results. Limitations: sample size, intraclass variability of the data.	1) M (no criterion about global cognitive functions, even if MMSE scores were relatively high) 2) L 3) L 4) L 5) L 6) L → Low risk of bias

Asai et al., 2018 [3]	537 community-dwelling older adults: 103 fallers (77.5 ± 6 y.; 68 F; RDST: 9.5 ± 3.1) and 434 non-fallers (76.5 ± 6.4 y.; 278 F; RDST: 9.6 ± 2.8); Inclusion criteria: aged 60 years-old and older, ability to walk independently with or without an assistive device, no physical or social care services from the local government, no self-reported neurological disorders that could affect mobility or balance; Exclusion criteria: inability to perform the ST- or DT-TUG, inability to understand the DT method because of severe cognitive impairment, incomplete data on any of the measurements.	**Retrospective** study; Self-administered questionnaire; Definition of a fall: [39].	Motor task: **TUG** test (walking at a comfortable and safe pace) Concurrent cognitive task: **mental tracking/working memory task**: serial-1 subtraction aloud from 100 Instructions: no instructions given regarding which task to prioritize Independent variables & analysis: completion time, last number spoken, backward counting speed ((100-last number counted)/completion time), DTC (sort of proportionate difference, with the mean completion time among ST and DT as divisor); Unpaired t-tests for group comparisons + multivariate logistic regression models with history of falls as dependent variable and with covariates (age, sex, height, weight and RDST score) + final logistic regression model with significant and uncorrelated TUG-related variables + ROC curve → AUC, cut-off value, sensitivity, specificity → classification into 4 fall risk groups and ORs + final logistic regression model applied on well-functioning (ST-TUG score < 7 s), transitional-functioning (ST-TUG score = 7-16 s) and frail groups (ST-TUG score > 16 s)	**(1) Yes, (2) Yes & (3) Yes – additional value:** Fallers took significantly **longer to complete ST-TUG** (p = 0.002) and presented a **lower DTC value** (p = 0.13) in comparison with non-fallers. Either in separate regression models or in a common regression model, even after adjustment for covariates, **ST-TUG score and DTC value** were **significantly associated with fall history** (ST-TUG score: OR = 1.133, 95% CI = 1.029-1.249, p = 0.011, cut-off value = 7.98 s, AUC = 0.58, sensitivity = 46%, specificity = 71%; DTC value: OR = 0.984, 95% CI = 0.968-0.998, p = 0.032, cut-off value = 15.4%, AUC = 0.57, sensitivity = 70%, specificity = 44%). Compared to the other three fall risk groups, a **higher proposition of older adults from the fall risk group characterized by a slower ST-TUG score and a lower DTC value reported a history of falls**. Finally, **both above mentioned predictors were similarly significantly associated with falls history in the transitional functioning group** (ST-TUG time = 7-16 s; ST-TUG score: OR = 1.198, 95% CI = 1.019-1.408, p = 0.029; DTC: OR = 0.979, 95% CI = 0.958-0.997, p = 0.043), but **not in the well-functioning group** (ST-TUG score < 7 s). Limitations: cross-sectional study → not possible to establish a causal relationship between TUG-related variables and the occurrence of a fall, various potential bias affecting the results (e.g., recall bias due to a fall history obtained via a questionnaire, selection bias because of the relatively healthy lives of the participants, confounding bias such as executive function that can affect both fall risk and DT performance), no assessment of the effects of different concurrent tasks on the TUG test score, no comparison between the predictive validity of the DT-TUG test and the DT gait test.	1) M (no exclusion criterion regarding non-severe cognitive impairment, even if RDST scores were high) 2) L 3) L 4) L 5) L 6) L → Low risk of bias
Toma-Carus et al., 2019 [69]	367 community-dwelling older adults: 96 fallers (78 F/18 M; 71.5 ± 9/73.5 ± 8 y.; Clock Drawing Test score: 19 ± 2/20 ± 1) and 271 non-fallers (179 F/92 M; 70 ± 7/73 ± 8 y.; Clock Drawing Test score: 19 ± 2/19 ± 1); Inclusion criteria: aged 65 years-old and older, ability to walk and understand the study protocol by themselves; Exclusion criteria: diagnosis of dementia, Parkinson's disease or vertigo, Clock Drawing Test score < 18 (associated with	Cross-sectional (**retrospective**) study; Fall history over the last year; → Fallers = (# of falls ≥ 1); Definition of a fall: "inadvertently coming to rest on the ground, floor or other lower level, excluding intentional change in position to rest in furniture, wall or other objects" [76].	Motor task: **TUG** test Concurrent cognitive task: **mental tracking/working memory task:** serial-1 subtraction from 100 Instructions: "walk as quickly and safely as possible (…), and count as quickly and surely as possible" Independent variables & analysis: for TUG-ST and TUG-DT: time spent on the test task accomplishment; for TUG-DT: number of cognitive errors, cognitive stops and motor stops; DTC being a kind of proportionate difference (difference in time spent between TUG-ST and TUG-DT, divided by the	**(1) Yes, (2) Yes & (3) Yes:** History of falls was significantly positively correlated to mean TUG-ST and TUG-DT time spent, mean cognitive errors, mean cognitive stops and mean motor stops. Among **men**, **mean TUG-DT time spent** (p = 0.014), **mean cognitive stops** (p = 0.049), **mean motor stops** (p = 0.023), **DTC** (p < 0.001), **[TUG-DT time + cognitive stops]** (p = 0.006) **and [TUG-DT time + cognitive stops + cognitive errors]** (p = 0.021) were significantly **higher** in fallers compared to non-fallers. Regarding **women**, only significantly **greater [TUG-DT time + cognitive stops + cognitive errors]** (p = 0.045) **and mean motor stops** (p = 0.024) were found in fallers in comparison with non-fallers. In **men**, a **significant AUC for predicting risk of falls** was found for **mean TUG-DT time spent** (p = 0.014), **[TUG-DT time + cognitive stops]** (p = 0.006), **[TUG-DT time + cognitive stops + cognitive errors]** (p = 0.021) **and DTC** (p < 0.001), whereas it was only **for [TUG-DT time +**	1) L 2) L 3) L 4) L 5) L 6) L → Low risk of bias

	cognitive impairment and different types of dementia).		average score between both tasks); [TUG-DT time + cognitive stops], [TUG-DT time + cognitive stops + cognitive errors]; non-parametric Spearman's correlations + Mann-Whitney U tests in both sexes + AUC of ROC curve, cut-off values, sensibility and specificity	**cognitive stops]** (p = 0.046) **and [TUG-DT time + cognitive stops + cognitive errors]** (p = 0.036) in **women**. The **best predictor** (in terms of AUC) was **DTC in men** (0.764) and **[TUG-DT time + cognitive stops + cognitive errors] in women** (0.583). Limitations: cross-sectional design limiting the extraction of conclusions about the predictive value of the TUG, small sample size, reliability of the new variables [TUG-DT time + cognitive stops] and [TUG-DT time + cognitive stops + cognitive errors] not tested yet.	
Asai et al., 2020 [4]	649 community-dwelling older adults: 331 young-older adults (60–74 y.), with 78 fallers (72.1 ± 2.9 y.; 53 F; RDST: 10.6 ± 2.5) and 253 non-fallers (71.7 ± 2.8 y.; 164 F; RDST: 11 ± 1.7), and 318 old-older adults (≥ 75 y.), with 97 fallers (80.4 ± 3.6 y.; 69 F; RDST: 9.3 ± 2.9) and 221 non-fallers (80.8 ± 3.9 y.; 139 F; RDST: 9.1 ± 2.9) Inclusion criteria: aged 60 years-old and older, ability to walk independently with or without an assistive device; Exclusion criteria: inability to perform the ST- or DT-TUG, incomplete data on any of the measurements, self-reported neurological disorders that could affect mobility or balance.	Longitudinal observation study (**prospective**) study; 1-year follow-up; Definition of a fall: [39].	Motor task: **TUG** test (walking at a comfortable and safe pace) Concurrent cognitive task: **mental tracking/working memory task**: serial-1 subtraction aloud from 100 Instructions: no instructions given regarding which task to prioritize Independent variables & analysis: completion time, last number spoken, backward counting speed ((100-last number counted)/completion time), DTC (sort of proportionate difference, with the mean completion time among ST and DT as divisor); Mann-Whitney U tests + unpaired t-tests + multivariate logistic regression models with covariates (age, sex, height, weight, RDST score at baseline, change in RDST score and comorbidities)	**(1) Yes, (2) Yes & (3) Yes – additional value:** **In young-older adults**, fallers took **longer to perform ST-TUG** in comparison with non-fallers (p = 0.02). **Old-older adult fallers**, for their part, showed **lower DTC** than non-fallers (p = 0.005). Regarding **predictive power for risk of falls**, ST-TUG time was not significantly associated with the occurrence of falls in the follow-up year in young older adults anymore, after controlling for covariates such as RDST and backward counting speed during DT-TUG. However, **in old older adults**, a **longer ST-TUG time** (OR = 1.143, 95% CI = 1.018-1.285, p = 0.024) **and lower DTC value** (OR = 0.981, 95% CI = 0.963-0.999, p = 0.049) were significantly associated with falls occurrence, even after adding RDST at baseline, change in RDST score, backward counting speed during DT-TUG and comorbidities as covariates into the regression model. Therefore, **DT may provide an additional value in TUG for predicting falls among old-older adults**. Limitations: relatively low follow-up rate (649/987, 66%), potential selection bias, some data regarding falls were not obtained, potential additional confounders, quite easy cognitive task, no other concurrent task tested.	1) M (no exclusion criterion regarding cognitive impairment, even if RDST scores were high) 2) M (relatively low follow-up rate) 3) L 4) L 5) L 6) L → Moderate risk of bias

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Figure 1

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