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Review

The association between visuospatial neglect and balance and mobility post-stroke onset: A systematic review

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ABSTRACT

Background: Although previous narrative reviews have highlighted a potential association between visuospatial neglect (VSN) and balance disorders, to what extent different areas of balance and mobility could be affected is still unclear.
Objectives: This systematic review updates previous literature findings and systematically reviews sitting balance, standing balance and mobility outcomes.
Methods: PubMed, Web of Science, ScienceDirect, Naric-Rehabdata, PEDro and the Cochrane Trials Library were systematically searched. Methodological quality was assessed by the National Heart, Lung, and Blood Institute Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies. The association between VSN and sitting balance, standing balance and mobility (walking, stair climbing/descending and transfers) was investigated.
Results: In total, 48 studies were included (4595 stroke survivors): at least 1319 (29%) showed symptoms of VSN. VSN was associated with less independence during sitting, with an asymmetric posture toward the affected body side. For standing balance, we revealed a significant negative association between VSN and mediolateral stability and weight shifting, whereas only activities of daily living-related VSN was associated with weight-bearing asymmetry during static stance. While walking, patients with VSN laterally deviated from their path. Results were inconclusive regarding other aspects of mobility. The association between VSN and balance/mobility seemed to decrease over time.
Conclusions: Despite great heterogeneity in results, this study suggests that stroke survivors with VSN show specific deviations in posture and movement in the mediolateral direction. Although the association between VSN and balance/mobility has been extensively investigated, explanatory studies evaluating underlying mechanisms of the frequently present association are lacking. Future studies should address this by combining clinical and instrumented assessment of balance and gait performance, preferably longitudinally to investigate the associations over time.

1. Introduction

Spatial neglect is a post-stroke disorder characterised by impaired awareness for stimuli located on the contralesional side of space [1]. This neglect results in problems with reporting, responding or orienting toward contralesional stimuli, which cannot be explained by sensory or motor impairments [1]. Spatial neglect is a heterogeneous disorder because it can encompass different clinical subtypes, which might involve different frames of references (egocentric, allocentric), processing modalities (e.g., sensory, representational) or regions of space (personal, peri-personal, extrapersonal) [2].

Visuospatial neglect (VSN) concerns neglect for visual stimuli and is the most frequently present and investigated type of spatial neglect [2]. VSN can be present after a right- or left-sided brain lesion but is more frequently present in right-sided brain lesions

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[3,4]. Within the first 2 weeks post-stroke, VSN occurs in approximately 50% of patients [5]. Spontaneous neurological recovery of VSN follows a natural logistic pattern of improvement within the first 12 to 14 weeks post-stroke. Afterward, the curve flattens and the severity of VSN remains merely invariant, leaving 40% of patients with initial VSN still with symptoms at 1 year post-stroke [5].

The high frequency and persistence of VSN might have major consequences; indeed, various studies suggest a negative association between VSN and post-stroke recovery of motor function and abilities [6–8]. Apart from the seemingly suppressive influence of VSN on the recovery of upper-limb strength and synergy acquisition [8], balance and mobility might also be affected owing to an impaired postural control system [6]. This spatially oriented system has 2 major behavioural goals [9,10]: on the one hand, it ensures a correct postural orientation proportionate to gravity, internal references and surroundings; on the other, it guarantees postural stability relative to the base of support to ensure the desired body orientation or the performance of controlled movement [9,10]. Postural control is thought to be organized around internal models, closely related to the "postural body scheme", which may represent a neural process incorporating sensory information from multiple modalities, resolving sensory ambiguity and integrating afferent and efferent information [9,10]. A spatial (orientational) bias of attention is a key characteristic of VSN [11] and might thus reflect a disruption in spatial information processing, which could impair body representation. This could result in impaired postural control and therefore impaired balance and functional mobility.

Although previous narrative reviews have highlighted a potential association between VSN and balance disorders [6], to what extent different areas of balance and mobility could be affected is still unclear. To fill this gap in the literature, this systematic review thoroughly updates previous research and systematically reviews sitting balance, standing balance and mobility outcomes.

2. Materials and methods

2.1. Protocol and registration

The protocol of this systematic review was registered on PROSPERO (registration No. CRD42020141817). This review adheres to the guidelines of Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) [12] (see Appendix A).

2.2. Search strategy and study selection

A systematic literature search was conducted on August 11, 2020 in PubMed, Web of Science, ScienceDirect, Naric-Rehabdata, PEDro and the Cochrane CENTRAL Library ('Trials' subsection). Search queries were built by using the following free-text terms as well as medical subject headings: "visuospatial neglect", "stroke", "balance", "gait" and their synonyms (see Appendix B). No restrictions or filters were added. We included articles that:

- investigated adult stroke survivors with no restrictions on lesion type or location;
- evaluated an association between VSN and balance or mobility by comparing patients with and without VSN or by evaluating this association by correlation or regression analyses;
- were original research (i.e., no clinical answers, reviews or meta-analyses);
- were written in English, German or Dutch.

For intervention studies, only baseline characteristics were considered because we were not interested in effects of any intervention. We excluded studies that were:

- unavailable in full text format even after contacting the authors;
- were case studies, because this does not allow to compare patients with and without VSN;
- evaluated balance/mobility in a virtual environment because of the inability to evaluate whether potential associations with balance/mobility are due to VSN or exposure to virtual environments;
- investigated a specific subgroup of patients with pusher syndrome: this complex multifactorial disorder results in a specific clinical behaviour in which patients actively push themselves away from the midline (straight) position [13]. Owing to the multifactorial nature of the disorder, evaluating the sole contribution of VSN to the outcome in this subgroup of stroke patients would be difficult.

Screening on the title, abstract and full text was performed by two independent reviewers (EE, TVC). During full text screening, reference lists of included studies were screened for secondary literature. Disagreements between reviewers were resolved by discussion.

2.3. Definitions

Predefined definitions concerning the criteria related to VSN, balance and mobility were used to decrease the potential for ambiguity in article selection. VSN was defined as a cognitive disorder characterised by impaired awareness of visual stimuli located on the contralesional side of space [1]. We included studies that adhered to this definition, even if no specific diagnostic test for VSN was used. If specific diagnostic tests were used, we distinguished between isolated (paper-and-pencil) tests (e.g., Star Cancellation Test), test batteries (e.g., Behavioural Inattention Test) and tests evaluating VSN during activities of daily living (ADL) with observational scales (e.g., Catherine Bergego Scale [CBS]). When VSN is assessed during ADL using observational scales, such tests evaluate more than solely VSN (e.g., auditive, tactile, motor and body neglect) without providing a distinction between these forms. Because they also evaluate VSN and because of the widespread use of the tests to measure VSN, studies using such scales were not excluded but were referred to as evaluating "ADL-related VSN" [14].

Considering balance and mobility, 3 main categories were defined, "sitting balance", "standing balance" and "mobility", based upon definitions of the International Classification of Functioning, Disability and Health [15]. "Sitting balance" is defined as 'the ability to maintain a sitting posture in static or dynamic situations' [15]. "Standing balance" is described as 'the dynamics of a standing body posture in order to prevent falling, whose assessment may be performed under both static or dynamic circumstances' [15]. Concerning standing and sitting balance, static circumstances are situations in which the body is sitting or standing quietly, whereas within dynamic situations, the body is moving within the base of support (such as sit-to-stand [STS] ability or reaching) [9]. Finally, the definition of mobility is "moving by transferring from one place to another (e.g., by changing base of support) such as during walking, stair climbing and transfers (e.g., bed-to-chair) [15]. All variables of interest could be assessed with clinical or instrumented methods. "Clinical methods" refer to clinical assessment scales (such as the Berg Balance Scale) without using any instrumented device, whereas "instrumented methods" refer to biomechanical assessments using such devices (e.g., force plates or gait analysis instruments).

2.4. Quality assessment

Risk of bias of included studies was assessed with the National Heart, Lung, and Blood Institute (NIHLBI) Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies [16]. For intervention studies, the same tool was used because only the pre-intervention characteristics of participants were investigated. Therefore, they were considered cross-sectional studies. This quality assessment tool assesses internal validity, including sources of bias (e.g., patient selection and detection), confounding factors, study power, the strength of the association between factors and outcomes, and other factors. It scores risk of bias by rating "yes", "no" or "cannot determine/not reported/not applicable" for each criterion. One point is rewarded for every "yes" given, indicating a low risk of bias. The criteria were adjusted to be more consistent with the research objectives (see Appendix C). Because no categories of methodological quality are predefined by the NIHLBI, quality was estimated by calculating percentiles to subcategorise studies as low, moderate and high methodological quality. Studies within percentiles 10–20 (score < 7) were considered at "low" methodological quality, studies with percentiles 30–60 (score 7–8) at "moderate" methodological quality and studies within percentiles 70–100 (score ≥ 9) at "high" methodological quality.

2.5. Data extraction and analyses

The following data were extracted by 2 independent reviewers (EE, TVC) from the included studies: authors, year, study design, number of participants with and without VSN, age, time post-stroke at inclusion, time(point) post-stroke of final assessment for longitudinal studies, VSN assessment, the evaluated outcomes for balance (sitting vs. standing) or mobility and their subcategories, and main findings of the studies. Tables 2–5 show further which assessment scales and methods were used to evaluate the different outcome categories.

3. Results

3.1. Study selection

In total, 1631 unique articles were retrieved. Considering screening on "title and abstract" and "full text", we found 74% and 85% agreement between the reviewers, respectively. All ambiguities were resolved during discussion, and ultimately, 48 articles were included (Fig. 1).

3.2. Risk of bias (Table 1)

Agreement between the reviewers concerning risk of bias was 96%, and disagreements were successfully resolved during discussion. Scores ranged from 4 to 12 out of 14. All but 2 studies received a zero on item 5, which evaluates sample size justification and power description. In addition, item 13 scored positive for every study, because none of the studies experienced loss to follow-up of > 20%. Percentiles were calculated to classify studies according to methodological quality. Nine studies were of poor methodological quality [17–25], 21 studies moderate methodological quality [26–46] and 18 studies good methodological quality [47–64].

3.3. Participants and descriptive data

Of the 48 included studies, 21 were cross-sectional [18,19,21–29,31,32,34,35,37,44,45,48,57,64] and 26 were longitudinal [17,20,30,33,36,38–43,47,49–56,58–62,64]. A total of 4595 stroke survivors were studied; at least 1319 (29%) showed

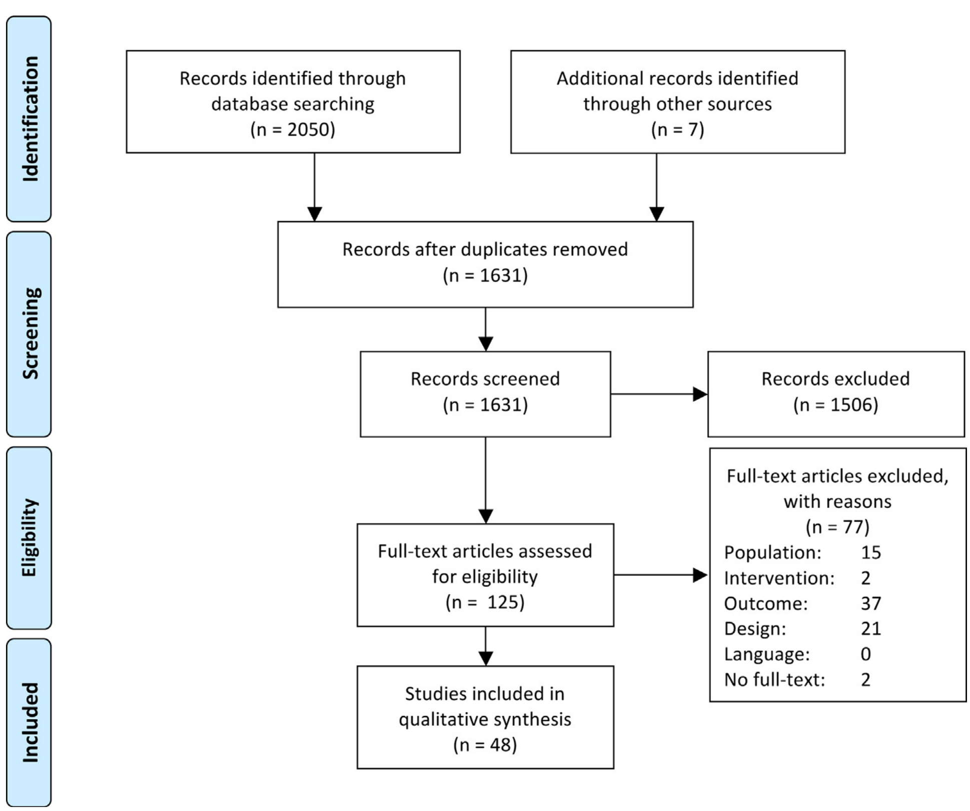

Fig. 1. Flowchart of the selection of eligible studies [12].

Table 1
Methodological quality items per study.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total Y	Total N/NA/NM	MQ
Alexander et al., 2009 [26]	Y	Y	N	Y	N	N	N	Y	Y	N	Y	Y	Y	NM	8	6	Moderate
Barra et al., 2009 [27]	Y	Y	N	Y	N	N	N	Y	Y	N	Y	N	Y	N	7	7	Moderate
Bonan et al., 2004 [28]	Y	Y	N	Y	N	N	N	N	Y	N	Y	N	Y	Y	7	7	Moderate
Bonan et al., 2006 [29]	Y	Y	N	Y	N	N	N	N	Y	N	Y	N	Y	Y	7	7	Moderate
Bonan et al., 2007 [30]	Y	Y	N	Y	N	N	Y	N	Y	N	Y	N	Y	N	7	7	Moderate
Colombo et al., 2019 [31]	Y	Y	Y	Y	N	N	N	N	Y	N	Y	N	Y	Y	8	6	Moderate
Dai et al., 2014 [32]	Y	Y	Y	Y	N	NM	N	N	Y	N	Y	N	Y	Y	8	6	Moderate
de Haart et al., 2004 [47]	Y	Y	N	Y	N	Y	Y	N	Y	Y	Y	Y	Y	Y	11	3	Good
de Haart et al., 2005 [33]	Y	Y	N	Y	N	N	Y	N	Y	N	Y	N	Y	Y	8	6	Moderate
Ferreira et al., 2015 [17]	Y	N	N	Y	N	N	NM	N	N	N	N	N	Y	Y	4	10	Poor
Genthon et al., 2008 [48]	Y	Y	N	Y	N	Y	N	Y	Y	N	Y	N	Y	Y	9	5	Good
Goldie et al., 1999 [49]	Y	Y	N	Y	N	N	Y	N	Y	Y	Y	N	Y	Y	9	5	Good
Goto et al., 2009 [18]	N	Y	Y	Y	N	N	NM	N	N	N	Y	N	Y	Y	6	8	Poor
Huitema et al., 2006 [34]	Y	Y	N	Y	N	Y	N	N	Y	N	Y	N	Y	Y	8	6	Moderate
Ishii et al., 2010 [35]	Y	Y	N	Y	N	Y	N	N	Y	N	Y	N	Y	Y	8	6	Moderate
Jackson et al., 2000 [50]	Y	Y	Y	N	N	Y	N	N	Y	N	Y	Y	Y	Y	9	5	Good
Kalra et al., 1997 [19]	Y	N	N	Y	N	Y	N	N	Y	N	Y	N	Y	N	6	8	Poor
Katz et al., 1999 [36]	Y	Y	N	Y	N	Y	Y	N	Y	N	N	N	Y	N	7	7	Moderate
Kawanabe et al., 2018 [37]	Y	Y	N	Y	Y	N	N	N	N	N	Y	N	Y	Y	7	7	Moderate
Kimura et al., 2019 [51]	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	N	Y	Y	11	3	Good
Kinsella et al., 1980 [38]	Y	Y	N	Y	N	N	Y	N	N	Y	Y	N	Y	Y	8	6	Moderate
Kinsella et al., 1985 [52]	Y	Y	N	Y	N	N	Y	N	Y	Y	Y	N	Y	Y	9	5	Good
Kollen et al., 2005 [53]	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	N	Y	N	9	5	Good
Maeshima et al., 1997 [39]	Y	N	N	N	N	N	Y	N	Y	Y	Y	N	Y	Y	7	7	Moderate
Mercer et al., 2014 [54]	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y	12	2	Good
Morone et al., 2015 [55]	Y	Y	Y	Y	N	Y	Y	N	Y	N	Y	N	Y	N	9	5	Good
Morone et al., 2018 [40]	Y	Y	Y	Y	N	Y	N	N	N	N	Y	N	Y	NM	7	7	Moderate
Nijboer et al., 2013 [56]	Y	Y	NM	Y	N	N	Y	N	Y	Y	Y	N	Y	Y	9	5	Good
Nijboer et al., 2014 [57]	Y	Y	N	Y	N	Y	N	Y	Y	N	Y	N	Y	Y	9	5	Good
Paolucci et al., 1998 [41]	Y	Y	Y	Y	N	Y	NM	N	N	N	Y	N	Y	Y	8	6	Moderate
Paolucci et al., 2001a [58]	Y	Y	N	Y	N	Y	Y	N	Y	N	Y	N	Y	Y	9	5	Good
Paolucci et al., 2001b [59]	Y	Y	Y	Y	N	N	Y	N	Y	Y	Y	N	Y	Y	10	4	Good
Paolucci et al., 2008 [60]	Y	Y	N	Y	N	Y	Y	N	Y	N	Y	N	Y	Y	9	5	Good
Petrilli et al., 2002 [42]	Y	Y	Y	Y	N	N	N	N	N	N	Y	N	Y	N	6	8	Poor
Perry et al., 2006 [20]	Y	Y	Y	Y	N	Y	Y	N	N	N	N	N	Y	N	7	7	Moderate
Rousseaux et al., 2013 [21]	Y	Y	N	Y	N	N	N	N	Y	N	Y	N	Y	N	6	8	Poor
Stapleton et al., 2001 [61]	Y	Y	N	Y	N	N	Y	N	Y	Y	Y	N	Y	N	8	6	Moderate
Stein et al., 2009 [43]	Y	N	Y	Y	N	Y	Y	N	Y	N	Y	NM	Y	Y	9	5	Good
Sturt et al., 2013 [46]	Y	Y	NM	Y	N	NM	N	N	Y	N	Y	N	Y	Y	7	7	Moderate
Tarvonen-Schröder et al., 2020a [64]	Y	Y	Y	Y	N	NM	N	Y	Y	N	Y	Y	Y	Y	10	4	Good
Tarvonen-Schröder et al., 2020b [63]	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y	Y	12	2	Good
Taylor et al., 1994 [22]	Y	N	Y	Y	N	NM	N	N	Y	N	Y	N	Y	N	6	8	Poor
Tromp et al., 1995 [23]	Y	N	N	N	N	NM	N	N	Y	N	Y	N	Y	N	4	10	Poor
Tyson et al., 2006 [24]	Y	Y	N	Y	N	N	N	N	Y	N	Y	N	Y	N	6	8	Poor
van Nes et al., 2008 [44]	Y	N	Y	Y	N	Y	N	N	Y	N	Y	N	Y	N	7	7	Moderate
van Nes et al., 2009a [62]	Y	Y	N	Y	N	N	Y	N	Y	Y	Y	N	Y	Y	9	5	Good
van Nes et al., 2009b [45]	Y	Y	N	Y	N	N	N	N	Y	N	Y	N	Y	Y	7	7	Moderate
Yelnik et al., 2006 [25]	Y	Y	N	Y	N	N	N	N	Y	N	Y	N	Y	N	6	8	Poor

Maximum obtainable score: 14. Max: maximum possible; MQ: level of methodological quality based on percentiles; N: no; NA: not applicable; NM: not mentioned; Y: yes.

symptoms of VSN, with mean or median age from 52 to 77 years. All except 3 studies [17,20,42] reported a standardized assessment to detect VSN, with great variability in tools used. Paper-and-pencil tests were used most frequently, by 39 studies [18,19,21–25,27–35,37–41,43,45–47,49,50,52–62]. Ten studies used only a paper-and-pencil test to assess VSN [22,28,45,46,49,53,56,57,61,62], 26 studies used a paper-and-pencil test combined with other VSN tests [18,19,21,23–25,27,29–31,33–35,37–41,47,50,52,54,55,58–60], and 3 studies used paper-and-pencil tests within a complete test battery for VSN, namely the Behavioural Inattention test [32,36,43]. VSN was assessed 6 times by using observation, with a computerized visual reaction-time test [44], with the National Institute of Health Stroke Scale (NIHSS) neglect item [26], without reporting a scale [20], and by using the CBS (ADL-related VSN) [21,27,65]. Assessment with the NIHSS neglect item was not combined with other tests to detect VSN. The CBS was used in 3 studies in isolation [48,63,64] and in 2 combined with paper-and-pencil tests [21,27]. In only 8 studies was VSN evaluated on different levels (e.g., measured as a continuous variable [severity] [26,27,48,53,54,63,64] or divided according to regions of space affected [57]).

Considering the time post-stroke of the initial or single VSN and balance/mobility assessment, one study evaluated stroke patients in the acute phase [45], 31 in the early subacute phase [18–22,24,25,29–33,35–37,40,41,44,46,47,51,53–58,60,61,63,64], 4 in the late subacute phase [23,27,48,50] and 4 in the chronic phase post-stroke [26,28,34,62,66] according to the phases proposed by Bernhardt et al. [67]. Eight studies did not mention the time post-stroke [17,38,39,42,43,49,52,59] (Table 2).

3.4. Sitting balance (Table 3)

3.4.1. Clinical assessment

All studies demonstrated a significant negative relationship between VSN and sitting balance [22,36,37,45]. Patients with VSN were significantly more dependent considering static sitting [37], and the prevalence of abnormal sitting equilibrium was significantly greater in patients with than without VSN [36]. Also, an asymmetric sitting posture with the trunk shifted towards the

Table 2
Descriptive data.

Author	D	N (lesion side)	VSN+/VSN−	Age (SD or range) in years	TPS initial/single assess (SD or range)	CTPi	TPS final assess	VSN assessment tools
Alexander et al., 2009 [26]	CS	37 (19 R, 18 L)	7/30	Sym: 60.5 (14.4) Asym: 50.6 (15.4)	Sym: 38.3 (32.4) m Asym: 57.7 (53.2) m	Chronic	NA	NIHSS neglect item
Barra et al., 2009 [27]	CS	22 (13 R, 9 L)	NM	57.14 (14.04)	13 (7.5) w	Late subac	NA	Bell's test, line bisection test, Catherine Bergego Scale
Bonan et al., 2004 [28]	CS	40 (20 R, 20 L)	9/40	49.5 (16) (IQR 35–78)	19 (15) m (IQR 12–108)	Chronic	NA	Bell's test
Bonan et al., 2006 [29]	CS	30 (17 R, 13 L)	15/15	59 (IQR 21)	39,5 d (IQR 37)	Early subac	NA	Bell's test, line bisection test
Bonan et al., 2007 [30]	C	28 (14 R, 14 L)	8/20	57.5 (IQR 22)	22.5 d (IQR 33)	Early subac	6m	Bell's test, line bisection test, scene copy test
Colombo et al., 2019 [31]	CS	89 (46 R, 43 L)	22/67	VSN+: 72.13 (8.45) VSN−: 70.46 (9.98)	VSN+: 47d VSN−: 39 d	Early subac	NA	Bell's test, line bisection test
Dai et al., 2014 [32]	CS	60 (all R)	40/20	A + VSN+: 61.85 (13.68) A-VSN+: 62.00 (16.24) A-VSN−: 60.35 (9.60)	A + VSN+: 68.30 (41.35) d A-VSN+ 52.10 (28.98) d A-VSN−: 62.30 (55.70) d	Early subac	NA	Behavioural inattention test – conventional subtests
de Haart et al., 2004 [47]	C	37 (24 R, 13 L)	16/21	61.6 (12.9) (27–82)	10 (5.4) w (3.3–24.1)	Early subac	12w after recr	Dutch O-search test, line bisection test, First 6 items of the block design subtest of Wechsler Adult Intelligence Scale
de Haart et al., 2005 [33]	C	36 (23 R, 13 L)	15/21	61.8 (13.0) (27–82)	10.0 (5.5) w (3.3–24.1)	Early subac	12w after recr	Dutch O-search test, line bisection test, First 6 items of the block design subtest of the Wechsler Adult Intelligence Scale
Ferreira et al., 2015 [17]	C	201 (99 R/102 L)	19/182	56.9 (21–90)	NM	NM	6m after rehab	NM
Genthon et al., 2008 [48]	CS	41 (25 R, 16 L)	NM	58.8 (13.5)	93.0 (46.2) d	Late subac	NA	Catherine Bergego Scale
Goldie et al., 1999 [49]	C	42 (23 R, 19 L)	10/32	66 (IQR 50–76)	As soon as possible after adm	NM	8w after adm	Shape cancellation test
Goto et al., 2009 [18]	CS	247 (77 R[a])	10/67[a]	65.5 (10.5) (37–83)	51.7 d	Early subac	NA	Line bisection test, cancellation test, replication of picture of house/cube, drawing clock/human/hand, observation
Huitema et al., 2006 [34]	CS	20 (12 R, 8 L)	6/14	L VSN−: 55.9 (35.6–73.2) R VSN−: 59.5 (37.3–73.6) R VSN+: 67.5 (63.5–69.8)	L VSN−: 447 (202–692) d R VSN−: 819 (485–1023) d R VSN+: 406 (93–1066) d	Chronic	NA	Bell's test, line bisection test, letter cancellation test, double simultaneous stimulation test
Ishii et al., 2010 [35]	CS	12 (all R)	7/5	68.6 (9.9)	15.8 (9.4) d	Early subac	NA	Line bisection test, line crossing test
Jackson et al., 2000 [50]	C	119 (45 R, 67 L, 7 NM)	29/71 (19 NT)	54 (IQR 47–60)	13.4 (IQR 9.1–17.5) w	Late subac	Disch	Line bisection test, star cancellation test, copying a diagram, drawing a clock
Kalra et al., 1997 [19]	CS	146 (75 R, 71 L)	47/99	77.0 (8.2)	8 d	Early subac	NA	Visual and sensory confrontation tests, line bisection test, observation during activities
Katz et al., 1999 [36]	C	40 (all R)	19/21	VSN+: 57.4 (10.1) VSN−: 58.36 (8.0)	VSN+: 34.5 (10.9) d VSN−: 25.4 (9.0) d	Early subac	Disch	Complete behavioural inattention test
Kawanabe et al., 2018 [37]	CS	107 (50 R, 50 L, 7 both)	21/86	71.1 (12.9)	20.7 (27.4) d	Early subac	NA	Line bisection test, line cancellation test, and double-dot detection task[b]
Kimura et al., 2019 [51]	C	94 (all R)	56/38	69.9 (9.3)	VSN + CI+: 36.5 (28.3–45.5) d VSN + CI−: 33.0 (24.8–48.0) d VSN-CI−: 30.0 (17.8–42.0) d	Early subac	Disch	Stroke impairment assessment set

Table 2 (*Continued*)

Author	D	N (lesion side)	VSN+/VSN−	Age (SD or range) in years	TPS initial/single assess (SD or range)	CTPi	TPS final assess	VSN assessment tools
Kinsella et al., 1980 [38]	C	31 (14 R, 17 L)	8/23	62 (33–74)	4-6 w after adm	NM	12w after adm	Albert's test, copy of complex figure of Rey, copy of drawings of a Maltese cross and flower, line bisection test, tri-modal double simultaneous stimulation
Kinsella et al., 1985 [52]	C	28 (13 R, 15 L)	8/20	62 (33–74)	4-6 w after adm	NM	18m PS	Albert's test, copy of complex figure of Rey, copy of drawings of a Maltese cross and flower, line bisection test, tri-modal double simultaneous stimulation
Kollen et al., 2005 [53]	C	101 (61 R, 41 L)	NM	65.4 (10.5)	7.3 (2.8) d	Early subac	52w PS	Letter cancellation test
Maeshima et al., 1997 [39]	C	22 (13 R, 9 L)	10/12	59.7 (8.8) (46–78)	Adm	NM	Disch	Line cancellation test, line bisection test, figure copying task
Mercer et al., 2014 [54]	C	32 (23 R, 10 L)	17/15	58.7 (17.3) (24–97)	1m	Early subac	6m PS	Letter cancellation test, start cancellation test
Morone et al., 2015 [55]	C	435 (187 R, 248 L)	76/359	71 (Q1 59, Q3 78)	14 d (Q1 9, Q3 25)	Early subac	Disch	Letter cancellation test, line cancellation test, sentence reading test, Wundt-Jastrow Area Illusion test
Morone et al., 2018 [40]	C	257 (142 R, 115 L)	60/197	69.91 (13.75)	18.35 (16.11) d	Early subac	Disch	Letter cancellation test, line cancellation test, sentence reading test, Wundt-Jastrow Area Illusion test
Nijboer et al., 2013 [56]	C	184 (115 R, 69 L)	53/131	VSN+: 55.5 (10.29) VSN−: 58.1 (11.33)	VSN+: 56.1 (29.84) d VSN−: 47.6 (20.31) d	Early subac	36m PS	Letter cancellation test
Nijboer et al., 2014 [57]	CS	81 (32 R, 45 L, 4 bilateral)	16/65	VSN+: 59.0 (12.7) VSN−: 55.84 (12.5)	VSN+: 41.0 (32.9) d VSN−: 36.5 (39.6) d	Early subac	NA	Shape cancellation test
Paolucci et al., 1998 [41]	C	440 (206 R/234 L)	83/357	63.55 (11.57)	54.14 (37.45) d	Early subac	Disch	Letter cancellation test, line cancellation test, sentence reading test, Wundt-Jastrow area illusion test
Paolucci et al., 2001a [58]	C	178 (all R)	89/178	VSN+: 69.10 (9.51) VSN−: 69.67 (9.60)	VSN+: 38.98 (15.40) d VSN−: 38.42 (17.06) d	Early subac	Disch	Letter cancellation test, line cancellation test, sentence reading test, Wundt-Jastrow area illusion test
Paolucci et al., 2001b [59]	C	141 (Non-PDT: R 60%, L 40%; PDT: R/L 50%)	32/109	Non-PDT: 58.72 (15.26) PDT: 62.54 (10.69)	Disch	NM	1y post-Disch	Letter cancellation test, line cancellation test, sentence reading test, Wundt-Jastrow area illusion test
Paolucci et al., 2008 [60]	C	500 (R 49%, L 51%)	117/383	68.19 (13.22) (10–97)	21.18 (7) d	Early subac	Disch	Letter cancellation test, line cancellation test, sentence reading test, Wundt-Jastrow area illusion test

Table 2 (*Continued*)

Author	D	N (lesion side)	VSN+/VSN−	Age (SD or range) in years	TPS initial/single assess (SD or range)	CTPi	TPS final assess	VSN assessment tools
Petrilli et al., 2002 [42]	C	93 (36 R, 57 L)	25/68	64.8 (29–90)	NM	NM	Disch	Not mentioned
Perry et al., 2006 [20]	C	55 (NM)	17/55	63.7 (16.6)	9.2 (10.9) d	Early subac	Disch	Not mentioned: occupational therapy exam[b]
Rousseaux et al., 2013 [21]	CS	42 (NM)	21/21	VSN+: 61.0 (14.4) VSN−: 55.5 (11.1)	VSN+: 59.6 (33.7) d VSN−: 64.7 (37.3) d	Early subac	NA	Line bisection, scene copying, bell's test, Catherine Bergego Scale
Stapleton et al., 2001 [61]	C	14 (10 R, 4 L)	7/7	60 (21–80)	34 (12–129) d	Early subac	6 w after recr	Star cancellation test
Stein et al., 2009 [43]	C	25 (all R)	12/13	VSN+: 77.7 (8) (65–87) VSN−: 74.1 (11) (53–89)	Adm	NM	5 w after disch	Behavioural Inattention Test
Sturt et al., 2013 [46]	I	18 (12 R, 6 L)	6/12	R&VSN+: 75.0 (13.3) R&VSN−: 67.8 (6.1) L&VSN−: 73.0 (15.9)	R&VSN+: 19.2 (12.1) d R&VSN−: 52.7 (48.2) d L&VSN−: 47.2 (60.7) d	Early subac	NA	Star cancellation test
Tarvonen-Schröder et al., 2020a [64]	CS	173 (69 R, 104 L)	126/47	R&VSN+: 65.1 (IQR 56.2-71.2) R&VSN−: 57.6 (IQR 51.1–67.2) L&VSN+: 66.5 (65.1-74.3) L&VSN−: 60 (56.1-71.4)	R&VSN+: 36.0 (IQR 23–62) d R&VSN−: 44.5 (IQR 16–83) d L&VSN+: 37.0 (IQR 17–72) d L&VSN−: 25.0 (IQR 18–43) d	Early subac	NA	Catherine Bergego Scale
Tarvonen-Schröder et al., 2020b [63]	C	173 (69 R, 104 L)	126/47	R&VSN+: 65.1 (IQR 56.2–71.2) R&VSN−: 57.6 (IQR 51.1–67.2) L&VSN+: 66.5 (IQR 65.1–74.3) L&VSN−: 60 (IQR 56.1–71.4)	R&VSN+: 36.0 (IQR 23–62) d R&VSN−: 44.5 (IQR 16–83) d L&VSN+: 37.0 (IQR 17–72) d L&VSN−: 25.0 (IQR 18–43) d	Early subac	Disch	Catherine Bergego Scale
Taylor et al., 1994 [22]	CS	38 (21 R, 17L)	13/25	72 (49–86)	6w	Early subac	NA	Star cancellation test
Tromp et al., 1995 [23]	CS	9 (all R)	5/9	56 (27–72)	21 (14) w (5–45)	Late subac	NA	Drawing task, letter cancellation test, line bisection test
Tyson et al., 2006 [24]	CS	75 (46 R, 29 L)	21/53	71.5 (12.2) (34–92)	21 (5) d	Early subac	NA	Star cancellation test, line bisection test
van Nes et al., 2008 [44]	CS	16 (8 R, 8 L)	NM	62.7 (7.6)	5.6 (1.7) w	Early subac	NA	Computerized visual reaction-time task
van Nes et al., 2009a [62]	C	53 (28 R, 25 L)	13/40	61.1 (10.3)	366 (10.4) d	Chronic	12 w after adm	Letter and star cancellation test
van Nes et al., 2009b [45]	CS	78 (44 R, 34 L)	17/61	VSN+: 74.9 (9.5) VSN−: 70.6 (12.9)	VSN+: 6.2 (2.4) d VSN−: 5.3 (2.4) d	Acute	NA	Letter and star cancellation test
Yelnik et al., 2006 [25]	CS	25 (14 R, 11 L)	11/14	52 (13)	30.1 (12.6) d	Early subac	NA	Bell's test, bisection of single line

Data are mean or median; D: design; C: cohort; CS: cross-sectional; I: interventional; CI: cognitive impairment; N: number of participants; R: right-sided stroke, L: left-sided stroke; CTPi: critical time period post-stroke of initial assessment; TPS: time post-stroke; d: days; w: weeks; m: months; y: years; SD: standard deviation; sym: symmetric; asym: asymmetric; VSN+: patients with VSN; VSN−: patients without VSN; NM: not mentioned; NA: not applicable; NT: not tested; subac: subacute; assess: assessment; adm: admission; rehab: rehabilitation; disch: discharge; recr: recruitment; PS: post-stroke.

[a] The authors performed a sub-analysis to evaluate the association of mobility and VSN on a sample of 77 patients with a right-hemispheric lesion only.

[b] Authors were contacted and they either provided the VSN test carried out or confirmed upon the definition of VSN.

paretic side was more prevalent in patients with than without VSN [22]. Moreover, VSN was a significant, negative predictor of outcome on both static and dynamic sitting balance [45].

3.4.2. Instrumented assessment: posturography

VSN was not significantly associated with centre of pressure (CoP) excursions [44,57] or velocities [44] in the anteroposterior direction. Neither were patients with and without VSN significantly different considering combined anteroposterior and mediolateral CoP excursions [57]. With regard to the mediolateral direction, 2 studies of moderate methodological quality found no significant association between VSN and mediolateral CoP excursions [29,44] or velocities [44], whereas one study of good methodological quality found a significant association for mediolateral CoP excursions [57]. Yelnik et al. [25] investigated sitting balance under optokinetic stimulation (OKS) and showed that VSN was unrelated to body tilt under OKS, but it was positively related to the stabilization reaction (i.e., ratio for total length of CoP displacement under OKS). In summary, although consensus was reached on an absent association in the anteroposterior direction, the association between CoP excursions in the mediolateral direction and VSN is still uncertain.

3.5. Standing balance (Table 4)

3.5.1. Clinical assessment

All studies demonstrated that the presence of VSN was significantly and negatively related to independence regarding STS from a toilet [37]. However, no association was found for STS from a (wheel)chair in studies of poor- and moderate-quality, respectively [20,37]. Concerning a combined assessment approach for static and dynamic standing balance, a significant independent

Table 3
Sitting balance.

Author	Sub-category	Assessment tool	Conclusion	Relationship VSN-Outc?	MQ
Clinical assessment					
Katz et al., 1999 [36]	Static	Observed abnormal sitting equilibrium	Prevalence of abnormal sitting equilibrium was > 3 times higher in VSN+ patients as compared to VSN− patients at admission and discharge (VSN+: 84%, VSN−: 24%)	Yes	Mod
Kawanabe et al., 2018 [37]	Static	Observed sitting on toilet	VSN+ patients were significantly less independent considering sitting on the toilet as compared to VSN− patients [VSN+: $\beta = -1.130$ (SE = 0.469, $P = 0.016$)]	Yes	Mod
Kawanabe et al., 2018 [37]	Static	Observed sitting in wheelchair	VSN+ patients were significantly less independent considering sitting in the wheelchair as compared to VSN− patients [VSN+: $\beta = -0.932$ (SE = 0.434, $P = 0.032$)]	Yes	Mod
Taylor et al., 1994 [22]	Static	Observed sitting on firm horizontal surface	A significantly greater proportion of VSN+ patients ($n = 8$) showed asymmetric sitting towards the affected side as compared to VSN− patients ($n = 1$)	Yes	Poor
van Nes et al., 2009b [45]	Static & dynamic	Trunk Control Test	VSN was a significant, negative predictor for the Trunk Control Test ($\beta = -14.065$, CI: [−24.474; −3.656])	Yes	Mod
van Nes et al., 2009b [45]	Static & dynamic	Trunk Impairment Scale	VSN was a significant, negative predictor for the Trunk Impairment Scale ($\beta = -2.674$, CI: [−5.002; −0.346])	Yes	Mod
Instrumented assessment: posturography					
Nijboer et al., 2014 [57]	Static: mediolateral direction	Average mediolateral CoP displacement (30s), in EO/EC conditions	Average mediolateral CoP was significantly displaced in patients with isolated peripersonal VSN as compared to VSN− patients (EO: U = 108.0, Z = −2.62, $P = 0.009$; EC: U = 129.0, Z = −2.24, $P = 0.025$)	Yes	Good
Bonan et al., 2006 [29]	Static: mediolateral direction	Course of each subject's CoP in the lateral plane for 25 seconds, mean CoP deviation, length of the course	No significant relation between balance and VSN	No	Mod
van Nes et al., 2008 [44]	Static: mediolateral direction	RMS of the COP amplitudes (ML), in EO/EC and stable/unstable conditions (feet supported)	No significant association between VSN and CoP amplitude in anteroposterior and mediolateral directions	No	Mod
van Nes et al., 2008 [44]	Static: mediolateral direction	RMS of the COP velocities (ML), in EO/EC and stable/unstable conditions (feet supported)	No significant association between VSN and CoP velocities in anteroposterior and mediolateral directions	No	Mod
Nijboer et al., 2014 [57]	Static: anteroposterior direction	Average anteroposterior CoP displacement (30 s), in EO/EC conditions	The average anteroposterior CoP was not significantly different between patients with and without VSN ($Z < -1.65$, $P > 0.099$)	No	Good
van Nes et al., 2008 [44]	Static: anteroposterior direction	RMS of the COP amplitudes (AP) in EO/EC and stable/unstable conditions (feet supported)	No significant association between VSN and CoP amplitude in anteroposterior and mediolateral directions	No	Mod
van Nes et al., 2008 [44]	Static: anteroposterior direction	RMS of the COP velocities (AP), in EO/EC and stable/unstable conditions (feet supported)	No significant association between VSN and CoP velocities in anteroposterior and mediolateral directions	No	Mod
Nijboer et al., 2014 [57]	Static: postural sway	Postural sway [shifts in CoP from the ideal weight distribution (i.e. 50–50%)] in EO/EC conditions	Postural sway was not significantly different between patients with and without VSN ($Z < -1.67$, $P > 0.095$)	No	Good
Yelnik et al., 2006 [25]	Static: optokinetic stimulation	Body tilt (lateral deviation of CoP), stabilization reaction	No significant correlation between VSN and body tilt under OKS. Significant correlation between the stabilization reaction and VSN for rightward ($P < 0.05$) and leftward rotation ($P < 0.019$)	Yes[a]	Poor

Outc: outcome; VSN+: patients with visuospatial neglect; VSN−: patients without VSN; MQ: methodological quality; CI: confidence interval; Mod: moderate; NM: not mentioned; CoP: centre of pressure; EO: eyes open, EC: eyes closed; RMS: root mean square error; OKS: optokinetic stimulation; stabilization reaction, [total length (Le) of CoP displacement], rLe = (OKS Le-basic Le)/basic Le.
[a] A significant relationship was found but only in certain cases (e.g. specific time points or types of VSN)

and negative association with VSN was found in 2 studies [45,62], and the opposite was found in one study [61].

3.5.2. *Instrumented assessment: posturography*

Only ADL-related VSN, measured with the CBS, was significantly related to weight-bearing asymmetry in favour of the non-paretic leg [27,65], whereas VSN evaluated with paper-and-pencil tests did not [27,35,47]. Additionally, ADL-related VSN was the best negative predictor of mediolateral instability [65] but was unrelated to anteroposterior instability [65]. One study found no relationship between VSN and an equilibrium score based on postural sway during the Sensory Organisation test [28]. During

Table 4
Standing balance.

Author	Sub-category	Assessment tool	Conclusion	Relationship VSN-Outc?	MQ
Clinical assessment					
Kawanabe et al., 2018 [37]	STS	Observed STS from toilet	VSN+ patients were less independent considering STS from the toilet bowl as compared to VSN− patients [VSN+: $\beta = -1.015$ (SE = 0.421, $P = 0.016$)]	Yes	Mod
Kawanabe et al., 2018 [37]	STS	Observed STS from wheelchair	VSN+ patients were not significantly different regarding independence in STS from wheelchair as compared to VSN− patients [VSN+: $\beta = -0.637$ (SE = 0.382, $P = 0.095$)]	No	Mod
Perry et al., 2006 [20]	STS	Functional independence measure: CAL	No significant difference in number of VSN+ and VSN− at admission between groups that improved STS CAL | VSN at admission was no significant predictor of STS CAL improvement over time (VSN+: OR = 2.16 ($P = 0.37$), CI: [0.40; 11.7])	No	Poor
van Nes et al., 2009b [45]	Static and dynamic	BBS	VSN was a significant, negative independent predictor for the BBS (VSN + $\beta = -9.934$, CI: [−16.843; −3.025])	Yes	Mod
Stapleton et al., 2001 [61]	Static and dynamic	BBS	Initial VSN presence was not significantly associated to initial BBS	No	Good
van Nes et al., 2009a [62]	Static and dynamic	BBS	VSN was significantly, negatively and independently longitudinally associated to the BBS	Yes	Good
Instrumented assessment: posturography					
Bonan et al., 2004 [28]	Static	Equilibrium score (based on postural sway during Sensory Organisation Test)	In right-hemispheric lesions, there was no significant difference in results between VSN+ and VSN− patients	No	Mod
Genthon et al., 2008 [48]	Static	Mean amplitude of the resultant CoP trajectories along the mediolateral axes	ADL-related VSN was a significant predictor for mediolateral instability [VSN+: $r = 0.31$ ($P < 0.05$)]	Yes	Good
Genthon et al., 2008 [48]	Static	Mean amplitude of the resultant CoP trajectories along the anteroposterior axes	ADL-related VSN was no significant predictor for anteroposterior instability [VSN+: $r = 0.15$ ($P > 0.05$)]	No	Good
Genthon et al., 2008 [48]	Static	WBA	ADL-related VSN was a significant predictor for WBA [$\beta = -0.29$ ($P < 0.05$)]	Yes	Good
de Haart et al., 2004 [47]	Static	WBA	No significant main or interaction effect of VSN on WBA	No	Mod
Barra et al., 2009 [27]	Static	WBA	ADL-related VSN has a significant relationship with WBA [$r = 0.53$ ($P < 0.01$)]. Non-ADL-related VSN did not have a significant relationship with WBA ($P > 0.05$)	Yes[a]	Mod
Ishii et al., 2010 [35]	Static	WBA	No significant relationship between VSN and the percentage of weight shifted onto the non-paretic leg in a static standing posture [$r = 0.27$ ($P = 0.40$)]	No	Mod
Ishii et al., 2010 [35]	Weight shifting	WBA	No significant relationship between VSN and the percentage of weight shifted onto the non-paretic leg in a dynamic standing posture [$r = -0.37$ ($P = 0.24$)]	No	Mod
Bonan et al., 2007 [30]	Weight shifting	Lateral stability limits, sagittal stability limits (course CoP for 52 seconds)	Significant relationship between initial VSN and lateral and sagittal stability limits at 6m post-stroke (r not given, $P \leq 0.01$)	Yes	Mod
de Haart et al., 2005 [33]	Weight shifting	Weight shifting speed; weight-transfer time asymmetry	VSN at baseline had a significant negative influence on the speed of weight shifting ($F1.34 = 4.21$; $P < 0.05$). Patients with VSN showed a relatively large weight-transfer time asymmetry (A = 1.4)	Yes	Mod
Mercer et al., 2014 [54]	STS	Peak vertical ground reaction force (PLEL)	Patients with the most severe VSN (lowest quartile on SCT) had lower rates of recovery for paretic leg weight-bearing during STS. Moreover, an increase in baseline SCT score of 9, corresponded to an increase in PLEL at 6m post-stroke of 0.0067 ($P = 0.013$)	Yes	Good

Outc: outcome; VSN+: patients with visuospatial neglect; VSN−: patients without VSN; MQ: methodological quality; CI: confidence interval; Mod: moderate; NM: not mentioned; STS: sit-to-stand; WBA: weight-bearing asymmetry; SCT: star cancellation test; CAL: caregiver assistance level; PLEL: paretic leg extremity loading; BBS: Berg Balance Scale.

[a] A significant relationship was found but only in certain cases (e.g. specific time points or types of VSN)

weight shifting, VSN was unrelated to weight-bearing asymmetry [35]. However, initial VSN was related to lateral and sagittal stability limits during weight shifting at 6 months post-stroke [30]. In addition, although VSN was negatively related to weight shifting speed over time [33], it did not affect the relative improvement of weight shifting speed [33]. Furthermore, patients with VSN showed a relatively large weight-transfer time asymmetry (i.e., average time needed to transfer weight from the non-paretic to paretic leg divided by average time needed to shift weight from the paretic to non-paretic leg) [33]. STS was evaluated in only one study using posturography: patients with the most severe VSN had lower paretic leg weight-bearing recovery during STS [54].

3.6. *Mobility (Table 5)*

3.6.1. *Walking*

3.6.1.1. Clinical assessment. Regarding gait speed, results were contradictory. A study of high-quality found no significant association between initial VSN and gait speed at 6 months post-stroke [54], but a moderate-quality study did [30]. In addition, 2 cross-sectional studies of moderate-quality that evaluated walking independence showed contradictory results: Huitema et al. [34] showed no significant relation, whereas van Nes et al. [45] showed that VSN was a weak although significant negative predictor of independent walking.

Table 5
Mobility: walking.

Author	Sub-category	Assessment tool	Conclusion	Relationship VSN-Outc?	MQ
Clinical assessment					
Bonan et al., 2007 [30]	Gait speed	10-m walk test	Significant relationship between initial VSN and comfortable walking speed at 6 m post-stroke ($P \leq 0.01$)	Yes	Mod
Mercer et al., 2014 [54]	Gait speed	10-m walk test	Baseline VSN score was no significant predictor for gait speed at 6m post-stroke [β 0.0093 ($P < 0.10$)]	No	Good
Ferreira et al., 2015 [17]	Independent community ambulation	Hoffer classification	No significant difference in number of patients with and without VSN, between the group who achieved independent community ambulation and the group who did not ($P = 0.09$)	No	Poor
Kimura et al., 2019 [51]	Walking independence	FIM walking score	Presence of VSN with other cogn imp at baseline is a significant negative predictor of independent gait at discharge (VSN+ with cogn imp: OR = 5.5, CI [1.19; 23.04]). Presence of VSN without other cogn imp at baseline is no significant predictor of independent gait at discharge	Yes[a]	Good
Jackson et al., 2000 [50]	Walking independence	NM	There were significantly more VSN+ patients in the group who did not achieve walking (47%) as compared to the group who did (20%)	Yes	Good
Petrilli et al., 2002 [42]	Walking independence	10-m walk test	No significant difference in number of patients with and without VSN, between the group who was ambulatory and the group who was not ambulatory	No	Mod
Paolucci et al., 2008 [60]	Walking independence	Walking outside without aid or supervision	VSN at admission was no significant independent predictor for independent walking outside without aid or supervision at discharge ($P > 0.05$)	No	Good
Paolucci et al., 2008 [60]	Walking independence	Walking inside without aid or supervision	The absence of VSN at admission was a significant positive predictor for walking inside without aid or supervision at discharge [VSN−: β = 1.58 (SE = 0.54) ($P = 0.004$)]	Yes	Good
Paolucci et al., 2008 [60]	Walking independence	Walking with a cane or other aid	VSN at admission was no significant independent predictor for independent walking with a cane or other aid at discharge ($P > 0.05$)	No	Good
Huitema et al., 2006 [34]	Walking independence	FAC	No significant difference in FAC score between patients with and without VSN ($P > 0.05$)	No	Mod
Kollen et al., 2005 [53]	Walking independence	FAC	VSN was weakly, but significantly and negatively associated to recovery of gait. More reductions in VSN is associated to more improvements in gait over time [β = −0.010 (SE = 0.006) ($P = 0.00$)]	Yes	Good
van Nes et al., 2009a [62]	Walking independence	FAC	After controlling for paresis, VSN did not remain significantly and longitudinally related to the FAC score (β = −0.037, SE = 0.022, $P = 0.09$)	No	Good
van Nes et al., 2009b [45]	Walking independence	FAC	VSN was a weak but significant negative predictor for the FAC (β = −0.964 [CI: −1.620; −0.309])	Yes	Mod
Jackson et al., 2000 [50]	Time to achieve walking	Time to achieve walking	VSN+ patients regain walking later (32w) as compared to VSN− patients (24w) ($P = 0.02$)	Yes	Good
Gait analysis					
Alexander et al., 2009 [26]	Walking	Gait speed	No significant correlation between NIHSS VSN scores and gait speed $r = -0.200$ ($P = 0.264$)	No	Mod
Goldie et al., 1999 [49]	Walking	Gait speed	No significant relation between VSN at baseline and gait speed 8w post-admission ($P > 0.05$); and between VSN and change in gait speed ($P > 0.05$)	No	Good
Huitema et al., 2006 [34]	Walking	Gait speed	No significant difference in comfortable gait speed between patients with and without VSN	No	Mod
Tromp et al., 1995 [23]	Walking	Gait speed	No significant difference between VSN+ and VSN− groups ($P > 0.05$) concerning gait speed ($P > 0.05$)	No	Poor
Alexander et al., 2009 [26]	Walking	Temporal symmetric or non-symmetric walking groups	Significantly higher NIHSS VSN scores in the temporal asymmetric group as compared to within temporal symmetric group ($P = 0.012$). All patients with VSN belonged to the asymmetrical group	Yes	Mod
Alexander et al., 2009 [26]	Walking	Temporal gait symmetry ratio	No significant correlation between NIHSS VSN scores and temporal gait symmetry ratio's [$r = 0.333$ ($P = 0.059$)]	No	Mod
Huitema et al., 2006 [34]	Walking	Walking trajectory ([absolute] maximum lateral deviation)	VSN+ have a larger lateral deviation within their walking trajectory as compared to VSN− patients ($P = 0.001$). VSN+ patients with good walking ability deviated towards the contralesional side; VSN+ with impaired walking ability deviated ipsilesionally	Yes	Mod
Tromp et al., 1995 [23]	Walking	(A) Presence of collision; (B) Path followed and side of collision	VSN+ patients experienced significantly more collisions compared to VSN− patients [F(2.24) = 45.31, $P < 0.001$], with 4 of the 6 patients following a left path with left collisions and 2 of the 6 patients following a right path with right collisions	Yes	Poor

Outc: outcome; VSN+: patients with VSN; VSN−: patients without VSN; CI: confidence interval; cog imp: cognitive impairments; m: months; w: weeks.
[a] A significant relationship was found but only in certain cases (e.g. specific time points or types of VSN).

Predictive modelling to evaluate whether initial VSN could predict walking independence at discharge revealed that the absence of VSN at admission was a positive predictor for independent walking inside without aid or supervision [60] but not for independent walking outside or independent walking with a cane or other aid at discharge [60]. Kimura et al. [51] showed that VSN at admission was only a significant, negative predictor for independent walking at discharge if other cognitive impairments were present. Regarding prevalence of VSN in independent walking groups, a study of good quality showed a significantly higher prevalence of VSN in the group who did not achieve independent walking versus the group who did [50]. These results are contradictory to the results of a poor- [17] and moderate- [42] quality study that found no such differences. Concerning the interaction between walking independence and VSN over time [53,62], conflicting evidence was found: Kollen et al. [53] showed that VSN was a negative and independent predictor for independent walking recovery, whereas van Nes et al. [62] did not (both high-quality studies). Finally, patients with VSN regained independent walking significantly later than patients without VSN [50].

3.6.1.2. Instrumented assessment: gait analysis (Table 5). All studies evaluating gait speed instrumentally showed no significant relation between VSN and gait speed [23,26,30,34]. VSN was not significantly related to temporal gait symmetry; however, all patients with VSN belonged to the asymmetric group [26]. Participants with VSN experienced significantly more collisions against door frames [23] and had significantly larger lateral deviations from their walking path [23,34]. This deviation was not uniform across patients because patients with VSN and accurate walking ability seemed to deviate toward the contralesional side, whereas those with impaired walking ability deviated toward the ipsilesional side [34].

3.6.2. Stairs (Table 6)

Stair climbing and descending was evaluated only clinically. On admission, patients with and without VSN did not significantly differ in stair climbing independence [39]. Similarly, studies found no relation between VSN and stair climbing independence at 4 or 12 weeks post-admission or 18 months post-stroke [38,52]. However, at 8 weeks post-admission, one study found a significant negative relationship indicating more dependency in patients with than without VSN [38]. VSN at admission was significantly negatively related to complete recovery of independent stair climbing [40]. Moreover, it was a negative predictor of and a prognostic factor for a greater risk of failing to achieve independent stair climbing at discharge [52]. Contrary to this, VSN at admission was not a significant predictor for independent partial stair climbing recovery [40]. Patients with VSN were more dependent in stair descending at 8 weeks but not 4 or 12 weeks post-admission or 18 months post-stroke [38,52].

For managing stairs (i.e., climbing and descending), patients with than without VSN were more dependent on admission and discharge [63,64]. Likewise, Nijboer et al. [56] evaluated the effect of VSN on the combination of independent stair climbing and walking, showing that patients with VSN were initially more impaired than those without, although the difference between groups decreased over time.

3.6.3. Transfers (Table 6)

Transfer ability was evaluated only clinically. Regarding bed-to-chair transfer ability, patients with than without VSN had a significantly lower independence on admission, but these differences diminished over time (i.e., discharge) [39]. At 4 or 7 weeks post-admission and 18 months post-stroke, patients with and without VSN did not differ in transfers, but the groups differed at 12 weeks post-admission [38]. Morone et al. [55] further showed that VSN at admission was a prognostic factor for greater risk of failing to achieve independent bed-to-chair transfer at discharge. Patients with than without VSN were more dependent in standing up from the floor at 4 and 12 weeks post-admission but not at 8 weeks post-admission and 18 months post-stroke. Three studies of good quality used an assessment approach that evaluated various transfers (e.g., bed-to-chair, toilet, shower/bath): patients with than without VSN were significantly more dependent in such transfers at admission and discharge [63,64]. This difference between groups decreased over time [56].

3.7. Clinical assessment batteries that combine balance and mobility tasks (Table 7)

Patients with than without initial VSN showed worse Postural Assessment Scale for Stroke (PASS) scores at discharge but not at 5 weeks post-discharge. Three moderate-quality studies evaluated the association between initial VSN and PASS scores on admission and baseline: 2 showed no significant association [43,46] and one did [30]. There was no association between scores on the PASS and performance on the line bisection test but there was a significant positive relation between scores on the PASS and performance on the Bell's test, scene copy test and CBS [21]. Dai et al. [32] showed that VSN had a negative relationship with PASS scores only if VSN was present in combination with anosognosia for hemiplegia.

Considering effectiveness on the Rivermead Mobility Index (RMI), reflecting improved mobility achieved during rehabilitation, patients with than without VSN were significantly less effective [58]. Moreover, VSN was an independent negative predictor of effectiveness on the RMI [58] and the risk that patients without VSN will have high effectiveness on the RMI was approximately 8 times higher than patients with VSN [41]. In contrast, presence of VSN was not associated with increased or decreased risk of low effectiveness on the RMI [41]. Regarding efficiency on the RMI, which is the amount of improvement in score divided by duration of rehabilitation, patients with than without VSN had a lower efficiency [58]. Additionally, VSN was an independent negative predictor of efficiency on the RMI [58]. VSN was unrelated to no response on the RMI [41]; however, there were significantly more patients with a low response on the RMI in the VSN than non-VSN group and fewer patients with a high response on the RMI in the VSN than non-VSN group [58].

Patients with than without VSN had significantly lower index scores on the Tinetti test, and VSN was negatively associated with this index score [31]. However, on all other scales, no association was found with VSN [18,24]. Kalra et al. [19] found that patients with than without VSN had even better accomplishment of functional tasks.

4. Discussion

This study updates previous research and systematically identifies the specific areas of balance and mobility in which stroke survivors with VSN show difficulties. By looking into clinical assessment methods as well as instrumented analyses, both dependency levels and quality of movement could be evaluated. Patients with than without VSN were more dependent during sitting [37,45] and they sat asymmetrically with their trunk deviated toward the paretic side [22]. However, posturographic studies evaluating mediolateral CoP displacements did not provide consensus on reduced sitting stability in patients with VSN [29,44,57]. The observed asymmetric sitting posture could be related to an impaired postural orientation, which could be associated with impaired verticality perception [6,9,10,68]. Misperception of verticality is frequently present in patients with VSN [69,70] and might induce a tilted internal reference frame. The observation that patients with VSN tend to sit asymmetrically could reflect the patients' aim to align themselves within this frame, a phenomenon sometimes referred to as "lateropulsion" [71]. Although this asymmetric position would be assumed to increase the effect of gravitational forces and heighten stability demands, the absence or inconclusiveness regarding increased CoP displacements indicates their ability to maintain stability by compensating for increasing mechanical demands [72].

Table 6
Mobility: clinical assessment only: stairs and transfers.

Author	Sub-category	Assessment tool	Conclusion	Relationship VSN-Outc?	MQ
Stairs					
Nijboer et al., 2013 [56]	Walking independence and managing stairs	FIM	VSN+ patients scored approximately 2.16 points lower compared to VSN− patient at start ($\beta = 2.16$ CI: [1.00; 3.33], $P < 0.001$). With each subsequent measurement (6m, 12m, 36m) the difference decreased with approximately 0.70 points VSN (VSNxTime: $\beta = -0.70$; CI: [−1.11; −0.30], $P < 0.001$)	Yes	Good
Kinsella et al., 1980 [38]	Stair climbing independence	Northwick Park ADL Index	VSN+ patients are significantly more dependent considering stair climbing at 8w post-admission as compared to VSN− patients ($P < 0.01$), but not at 4 and 12w post-admission	Yes[a]	Mod
Kinsella et al., 1985 [52]	Stair climbing independence	Northwick Park ADL Index	VSN+ patients are not significantly more dependent considering stair climbing at 18m post-stroke as compared to VSN− patients ($P > 0.05$)	No	Good
Maeshima et al., 1997 [39]	Stair climbing independence	BI	VSN+ and VSN− groups did not differ significantly considering stair climbing independence on admission and discharge ($P > 0.05$)	No	Mod
Morone et al., 2018 [40]	Stair climbing independence	BI: complete recovery of stair climbing	VSN+ at admission was a significant negative predictor for complete stair climbing recovery at discharge. VSN presence at admission reduced the possibility of complete stair climbing recovery by approximately 5.5 times (VSN: $\beta = -1.703$ (SE 0.853), $P = 0.046$, OR = 0.182)	Yes	Mod
Morone et al., 2018 [40]	Stair climbing independence	BI: partial recovery of stair climbing	VSN at admission was no significant independent predictor for partial stair climbing recovery at discharge	No	Mod
Morone et al., 2015 [55]	Stair climbing independence	BI	VSN at admission was a significant prognostic factor for a greater risk of failing to achieve independent stair climbing at discharge ($\beta = 1.701$ (SE 0.453), $P < 0.001$, CI: [2.252; 13.318], OR 5.47)	Yes	Good
Kinsella et al., 1980 [38]	Stair descending independence	Northwick Park ADL Index	VSN+ patients are significantly more dependent considering stair descending 8w ($P < 0.01$), but not at 4 or 12w ($P > 0.05$) post-admission as compared to VSN− patients	Yes[a]	Mod
Kinsella et al., 1985 [52]	Stair descending independence	Northwick Park ADL Index	VSN+ patients are not significantly more dependent considering stair descending at 18m post-stroke as compared to VSN− patients ($P > 0.05$)	Yes	Good
Tarvonen-Schröder et al., 2020a [64]	Managing stairs (climbing & descending)	FIM	R-sided stroke patients: Patients with VSN at admission [median 1 (IQR 1-4)] were significantly more dependent concerning managing stairs compared to those without VSN [median 6 (IQR 6–7)] ($P = 0.007$) at admission L-sided stroke patients: Patients with VSN at admission [median 1 (IQR 2–6)] were significantly more dependent with managing stairs compared to those without VSN [median 6 (IQR 6–7)] ($P < 0.0003$) at admission	Yes	Good
Tarvonen-Schröder et al., 2020b [63]	Managing stairs (climbing & descending)	FIM	R-sided stroke patients: Patients with VSN at admission [median 4 (IQR 1–5)] were significantly more dependent with managing stairs at discharge compared to those without [median 6 (IQR 4–6)] ($P = 0.04$). L-sided stroke patients: Patients with VSN at admission [median 3 (IQR 1–5)] were significantly more dependent with managing stairs at discharge compared to those without [median 6 (IQR 5–7)] ($P < 0.0003$)	Yes	Good
Transfers					
Kinsella et al., 1980 [38]	Bed-to-chair transfer independence	Northwick ADL Index	VSN+ patients are significantly more dependent considering transfer from bed-to-chair at 12w ($P < 0.01$), but not at 4w or 8w, post-admission as compared to VSN− patients ($P > 0.05$)	Yes[a]	Mod
Kinsella et al., 1985 [52]	Bed-to-chair transfer independence	Northwick ADL Index	VSN+ patients are not significantly more dependent considering transfer from bed-to-chair at 18m post-stroke as compared to VSN− patients ($P > 0.05$)	No	Good
Maeshima et al., 1997 [39]	Bed-to-chair transfer independence	BI (admission)	VSN+ patients had significantly lower transfer independence on admission as compared to VSN− patients (F = 5.46, df = 1, $P < 0.05$)	Yes	Mod
Maeshima et al., 1997 [39]	Bed-to-chair transfer independence	BI (discharge)	VSN+ and VSN− groups did not differ significantly at discharge considering transfers ($P > 0.05$)	No	Mod
Morone et al., 2015	Bed-to-chair transfer independence	BI	VSN at admission was a significant prognostic factor for a greater risk of failing to achieve independent transfer ability at discharge ($\beta = 1.856$ (SE 0.375), $P < 0.001$, CI [3.067; 13.353], OR 6.4)	Yes	Good
Kinsella et al., 1980 [38]	Standing up from the floor	Northwick ADL Index	VSN+ patients are significantly more dependent considering standing up at 4 ($P < 0.05$) and 12w ($P < 0.01$), but not at 8w ($P > 0.05$) post-admission as compared to VSN− patients	Yes[a]	Mod
Kinsella et al., 1985 [52]	Standing up from the floor	Northwick ADL Index	VSN+ patients are not significantly more dependent considering standing up from the floor at 18m post-stroke as compared to VSN− patients ($P > 0.05$)	No	Good
Nijboer et al., 2013 [56]	Transfer independence (various transfers)	FIM	VSN+ patients scored approximately 3.11 points lower compared to VSN− patient at start ($\beta = 3.11$, CI: [1.85–4.36], $P < 0.001$). With each subsequent measurement (6m, 12m, 36m) this difference decreased with approximately 1.01 points (VSNxTime: $\beta = -1.01$; CI: [−1.46; −0.58], $P < 0.001$)	Yes	Good
Tarvonen-Schröder et al., 2020[a][64]	Transfer independence (various transfers)	FIM	R-sided stroke patients: Patients with VSN at admission [median 5 (IQR 3–6)] were significantly more dependent concerning transfers compared to those without VSN [median 6.7 (IQR 6–7)] ($P = 0.006$) at admission L-sided stroke patients: Patients with VSN at admission [median 4 (IQR 2–6)] were significantly more dependent concerning transfers compared to those without VSN [median 7 (IQR 6–7)] ($P < 0.0003$) at admission	Yes	Good

Table 6 (*Continued*)

Author	Sub-category	Assessment tool	Conclusion	Relationship VSN-Outc?	MQ
Tarvonen-Schröder et al., 2020b [63]	Transfer independence (various transfers)	FIM	R-sided stroke patients: Patients with VSN at admission [median 6 (IQR 4.3–6)] were significantly more dependent concerning transfers at discharge compared to those without VSN [median 6.8 (IQR 6–7)] ($P = 0.01$) at admission L-sided stroke patients: Patients with VSN at admission [median 6 (IQR 4–7)] were significantly more dependent concerning transfers at discharge compared to those without VSN [median 7 (IQR 6.7–7)] ($P < 0.0003$) at admission	Yes	Good

Outc: outcome; VSN+: patients with visuospatial neglect; VSN−: patients without VSN; MQ: methodological quality; CI: confidence interval; Mod: moderate; NM: not mentioned; w: weeks; m: months; L: left, R: right, FIM: functional independence measures; BI: Barthel index; ADL: activities of daily living.
[a] A significant relationship was found but only in certain cases (e.g. specific time points or types of VSN).

Contrary to the observation in sitting, (ADL-related) VSN was associated with increased weight-bearing asymmetry favouring the non-paretic leg and increased mediolateral CoP excursions while standing. However, upright standing is an inherently more demanding posture owing to the height of the centre of mass relative to the base of support [9]. Hence, sitting stability as well as increased weight-bearing on the non-paretic leg might reflect the ability of patients with VSN to accurately compensate for their impairments. This was also seen when STS ability was evaluated. Patients with and without VSN were equally dependent when evaluated by clinical scales [20,37], but a high-quality study using posturography indicated that patients with severe VSN showed less recovery of paretic leg loading during standing [54]. Although this finding shows a difference between groups, it also indicates that even with severe VSN, patients were still able to incorporate compensatory strategies to perform the dynamic standing task. However, performing such tasks within a stimuli-free laboratory setting may simply not have been not challenging for patients to overload the attentional resources used by the postural control system to control balance [72]. Increased attentional load is assumed to decrease the ability to compensate for visuospatial deficits [73]. Previous research suggested the importance to assess patients in a lifelike, stimuli-dense environment, which indicates that VSN assessment tools incorporating dynamic aspects and high cognitive and motor load leave patients with VSN with less compensational abilities [74]. Studies specifically evaluating such balance and mobility tasks within demanding environments are lacking but would provide crucial insights into the role of VSN-specific compensation strategies for balance control.

Results regarding mobility tasks such as stair climbing and transfers were variable among studies. These tasks are inherently more complex as compared with, for example, static standing and therefore considered more sensitive to discover differences between patient groups. A reason for such inconclusive results might be the complexity of VSN itself. VSN can manifest in various ways, so it is a disorder with pronounced heterogeneity concerning its clinical manifestation. Therefore, the type of assessment method to detect VSN is crucial. Most studies included in this review assessed the presence of VSN by using paper-and-pencil tests, which solely evaluate peripersonal VSN and are therefore unable to map the whole complexity of the disorder, such as extrapersonal regions of space. Given that few studies have investigated extrapersonal VSN, how visual information is integrated across regions of space in healthy controls and in patients with VSN remains unclear [75]. Additionally, studies suggest that patients with only mild or moderate VSN can easily compensate for their deficit on paper-and-pencil tests because they lack complexity, interaction with the environment and therefore ecological validity concerning the cognitive/attentional demand of daily life [74,76–79]. Combining paper-and-pencil tests with tests that evaluate ADL-related VSN (such as the CBS, but also the Mobility Assessment Course [74,80]) might increase the probability of finding an association between VSN and balance or mobility. Because such ADL-related assessment methods also include dynamic mobility tasks, they will increase attentional load for patients to a greater extent, so they are inherently more demanding than cancellation tasks [78].

Only a few prospective studies used fixed measurement time points post-stroke, rather than a relative moment in time such as "at admission" or "at discharge" [53,54,66,81]. However, the use of fixed moments would reduce variation concerning time post-stroke and therefore increase comparability between studies. Of the studies using this, only 2 measured VSN repeatedly over time [53,56]. Because both VSN and balance or mobility are time-dependent outcomes, longitudinal assessment of both is crucial to evaluate their longitudinal association, especially since the results of this review suggest that the association decreases over time. Moreover, no studies combined clinical measurements with instrumented analyses. Clinical measurements have the tendency to evaluate balance and mobility on an activity level (e.g., if the patient can perform a functional task), whereas instrumented analyses evaluate how the task is actually performed, which is by definition on the body-function International Classification of Functioning, Disability and Health level [82]. Therefore, combining both would provide insights into underlying mechanisms of how VSN potentially affects certain aspects of balance and mobility.

5. Clinical implications

This study highlights the importance of a systematic assessment of post-stroke patients on VSN as well as different categories of balance and mobility, preferably repetitively throughout the patient's recovery process. VSN assessment should be assessed thoroughly by using a combination of paper-and-pencil tests and observational ADL-related scales. Moreover, other cognitive domains beyond visuospatial abilities should be assessed as well. Considering balance and mobility, individuals with VSN should be assessed dynamically within a lifelike stimulus-dense environment to increase cognitive load. Because this would reduce the patient's ability to compensate, it would allow for better clinical decision making (i.e., regarding rehabilitation strategies). In addition, balance and mobility tasks could be assessed by using a combined approach of clinical scales and instrumented analyses to gain further insight into the underlying mechanisms responsible for the individual's behaviour.

6. Limitations and strengths

A limitation was the restricted search strategy in that only articles written in English, German or Dutch were included. Therefore, potentially relevant studies might have been missed. In addition, the focus of this study was on VSN. The other sensory

Table 7
Clinical assessment scales: assessment batteries combining sitting & standing balance and mobility.

Author	Sub-category	Assessment tool	Conclusion	Relationship VSN-Outc?	MQ
Postural Assessment Scale for Stroke					
Bonan et al., 2006 [29]	PASS	S, Std, Mob	No significantly relation between balance and VSN	No	Mod
Bonan et al., 2007 [30]	PASS	S, Std, Mob	Significant relationship between initial presence of VSN and PASS score at admission, and PASS score at 6m post-stroke ($P \leq 0.01$). Significantly lower PASS score for patients with initial VSN as compared to patients without initial VSN at 6m [VSN−: 32 (SD 7); VSN+: 22 (SD 9) $P < 0.05$]	Yes	Mod
Dai et al., 2014 [32]	PASS	S, Std, Mob	Patients with VSN and anosognosia had a significantly lower PASS score as compared to patients with solely VSN or patients without VSN or anosognosia ($P = 0.009$)	Yes[a]	Mod
Rousseaux et al., 2013 [21]	PASS	S, Std, Mob	Scores on the scene copy test, bell's test and CBS test were weakly but significantly negatively associated with PASS scores ($P < 0.05$) (PASS vs. 1. Scene Copy test $r = -0.305$; 2. Bell's test: $r = -0.342$ 3. CBS: $r = -0.406$). The scores on the line bisection test were not [$r = -0.240$ ($P > 0.05$)]	Yes	Poor
Stein et al., 2009 [43]	PASS	S, Std, Mob	Patients with VSN on admission had significantly lower PASS scores as compared to patients without VSN at discharge ($P < 0.002$) but not at admission and 5 weeks post-stroke ($P > 0.002$[b])	Yes[a]	Mod
Sturt et al., 2013 [46]	PASS	S, Std, Mob	Baseline PASS scores prior to the intervention were not significantly different between the R&VSN+, R&VSN− and L&VSN− group [$F(2, 15) = 1.5$ ($P = 0.25$)]	No	Mod
Rivermead Mobility Index					
Bonan et al., 2007 [30]	RMI	S, Std, Mob	Significant relationship between initial VSN and RMI scores at 6m post-stroke ($P \leq 0.01$)	Yes	Mod
Huitema et al., 2006 [34]	RMI	S, Std, Mob	No significant difference in RMI score between patients with and without VSN	No	Mod
Paolucci et al., 2001a [58]	RMI	S, Std, Mob	The VSN+ group had significantly lower admission and discharge scores on the RMI ($z = -4.96$, $P < 0.001$)	Yes	Good
Paolucci et al., 2001b [59]	RMI	S, Std, Mob	The odds that patients with VSN at admission will have a significant decline in RMI score at follow-up are 3.01 times higher as compared to VSN− patients [OR VSN = 3.01, CI: [1.21; 7.50] ($P < 0.05$)]	Yes	Good
Paolucci et al., 1998 [41]	No response	S, Std, Mob	VSN was not significantly and independently associated with 'no response on RMI'	No	Mod
Paolucci et al., 2001a [58]	Low response	S, Std, Mob	There were significantly more patients with a low response on the RMI in the VSN+ group (27%) as compared to the VSN− group (6%) [$Chi^2 = 12.32$ ($P < 0.001$)]	Yes	Good
Paolucci et al., 2001a [58]	High response	S, Std, Mob	There were significantly less patients with a high response on the RMI in the VSN+ group (7%) as compared to the VSN− group (36%) [$Chi^2 = 19.94$ ($P < 0.001$)]	Yes	Good
Paolucci et al., 1998 [41]	Low effectiveness	S, Std, Mob	VSN was not significantly independently associated with 'low effectiveness on RMI'	No	Mod
Paolucci et al., 1998 [41]	High effectiveness	S, Std, Mob	The risk that patients without VSN will have a high effectiveness on the RMI is approximately 8 times higher than that of patients with VSN (RR = 7.95; CI: [2.45; 25.84])	Yes	Mod
Paolucci et al., 2001a [58]	Effectiveness	S, Std, Mob	The VSN+ group had a significantly lower effectiveness on the RMI as compared to the VSN− group ($F = 34.45$, $P < 0.001$)	Yes	Good
Paolucci et al., 2001a [58]	Effectiveness	S, Std, Mob	VSN+ was a significant and independent and negative predictor of effectiveness on RMI [$\beta = -0.23$ ($P < 0.005$)]	Yes	Good
Paolucci et al., 2001a [58]	Efficiency	S, Std, Mob	The VSN+ group had a significantly lower efficiency on the RMI as compared to the VSN− group $F = 40.21$ ($P < 0.001$)	Yes	Good
Paolucci et al., 2001a [58]	Efficiency	S, Std, Mob	VSN+ was a significant, independent and negative predictor of efficiency on RMI [$\beta = -0.31$ ($P < 0.001$)]	Yes	Good
Other scales					
Colombo et al., 2019 [31]	Tinetti test	S, Std, Mob	VSN+ group had significantly lower Tinetti Index scores compared to the VSN− group; VSN was significantly and negatively associated with the Tinetti Index score [$r = -0.347$ ($P < 0.001$)]	Yes	Mod
Goto et al., 2009 [18]	"Tomei"[a] Mobility Level	S, Std, Mob	No significant difference between VSN+ and VSN− patients considering Tomei mobility level ($P = 0.0879$)	No	Poor
Kalra et al., 1997 [19]	Sitting–Standing–Walking classification	S, Std, Mob	VSN+ group (median 2.5) had a significantly better balance classification as compared to VSN− group (median 2) ($P = 0.01$)	No	Poor
Tyson et al., 2006 [24]	Brunel Balance Assessment	S, Std, Mob	VSN was not a significant and independent predictor for balance disability ($P = 0.714$)	No	Poor

Outc: outcome; S: Std, Mob, sitting, standing, mobility; VSN+: patients with visuospatial neglect; VSN−: patients without VSN; sig: significant(ly); CI: confidence interval; NM: not mentioned; PASS: Postural Assessment Scale for Stroke; RMI: Rivermead Mobility Index.
[a] A significant relationship was found but only in certain cases (e.g. specific time points or types of VSN).
[b] Bonferonni corrected *P*-value.

domains, apart from the vision, might also negatively affect balance and mobility. However, most research concerns visual neglect, and most conventional and innovative neglect tests are visual in nature. Neglect in other domains (e.g., auditory, tactile, motor) is less studied and rarely tested in clinical settings. Focus on different sensory domains, both in research and clinical practice, would improve our understanding of neglect in general. Nevertheless, the current review has given us important insights into the interactions between lateralised visual attention deficits and motor impairments as well as indications for future research and clinical practice. A strength of this study is its focus on both clinical measures and instrumented analyses, which enabled the evaluation of balance and mobility performance on the accomplishment as well as the underlying biomechanics.

7. Conclusion

Despite great heterogeneity in results of included studies, this review suggests that stroke survivors with VSN show specific deviations in posture and movement in the mediolateral direction. Indeed, VSN was associated with less independence during sitting, with an asymmetric posture toward the paretic side. During standing, studies showed a significant negative association between VSN and mediolateral stability and weight shifting, whereas only ADL-related VSN was associated with weight-bearing asymmetry during static stance. These mediolateral aspects were also evident during walking because patients with VSN laterally deviated from their path. Regarding other facets of mobility, results were generally inconclusive. Explanatory studies assessing the underlying mechanisms for patients' behaviour are lacking. However, these mechanisms should be addressed in future research by combining clinical and instrumented assessment methods, preferably within a longitudinal study design with fixed time points to improve study comparability. In addition, balance and mobility should be assessed dynamically within a lifelike stimulus-dense environment to increase cognitive load and decrease the patient's ability to compensate for VSN-related deficits. This assessment will allow for better clinical decision making (e.g., regarding rehabilitation strategies).

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Disclosure of interest

The authors declare that they have no competing interest.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.rehab.2020.10.003.

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