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Review Article

Neurologic and musculoskeletal effects of tilt-table standing on adults: a systematic review

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Abstract. [Purpose] Tilt table use is associated, most often, with the assessment of syncope. However, it also has applications for patients with neurologic and orthopedic problems. These applications do not appear to be widely applied. The purpose of this review, therefore, was to summarize the research literature addressing the use of tilt tables for treating specific musculoskeletal and neurologic impairments in adults. [Methods] Relevant literature was identified by searches of the PubMed, CINAHL, and Scopus databases and hand searches (December 2018 and October 2020). The methodological quality of the identified research articles was assessed using the PEDro scale. [Results] Of 482 unique articles identified, 20 matched the eligibility criteria of the review and were included. The studies varied widely in the populations studied, procedures used, and responses reported. The studies provide limited support for tilt table standing as an intervention. [Conclusion] However, evidence that some patients with neurologic conditions may respond positively to tilt-table standing is available. Among such individuals are those with decreased ankle range of motion, positive neurologic signs in the lower limbs, and decreased levels of consciousness.

Key words: Tilt-table, Range of motion, Spasticity

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INTRODUCTION

The Guide to Physical Therapist Practice describes one component of the physical therapist management of patients as the "prescription, application, and, as appropriate, fabrication or modification" of assistive technology- of which tilt-tables can be considered an example[1)]. A survey of physical therapists working in intensive care units in Australia indicated that a majority used tilt-tables[2)]. An observational study of patients with stroke demonstrated that most of those treated on tilt-tables tolerated the procedure well[3)]. These facts notwithstanding, we have not observed widespread therapeutic use of tilt-tables in clinical settings in the United States- perhaps because of the cost of tilt-tables, the need to monitor hemodynamic status during tilt-table standing, or the perception that tilt-table standing is a passive activity. The purpose of this systematic review, therefore, was to determine whether tilt-table standing is justified on the basis of neurologic or musculoskeletal effects accompanying the intervention.

METHODS

Articles addressing the use of tilt-table standing to achieve neurologic or musculoskeletal benefits for adults were identified by an electronic search of 3 databases (PubMed, CINAHL, Scopus) on December 20, 2018 and again on October 15, 2020. The electronic searches used the search string "Tilt-table AND (Physical Therapy OR Rehabilitation)". A hand-search was also conducted. To be included an article had to report neurologic or musculoskeletal effects of standing with assistance

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of a conventional tilt-table. Articles reporting use of a tilt-table in combination with other interventions were included if tilt-table standing was judged to be a fundamental component of the intervention. Articles focused on use of robotic tilt-tables, standers or tilting beds were excluded. Articles were also excluded if written in a language other than English.

The 2 authors independently reviewed potentially relevant articles identified by the computerized and hand searches. They initially selected articles based on their titles and abstracts. When the titles or abstracts provided insufficient information to guide selection, the full text of articles was consulted. Included articles were perused by the authors for information about study participants, interventions, and neurologic and musculoskeletal effects of the interventions. The PEDRO scale was used to grade the quality of the included studies[4].

RESULTS

Three hundred forty-four unique articles were identified by the computerized searches. Twenty-two additional articles were found using hand searches (Fig. 1). Ultimately 20 articles were identified as relevant on the basis of inclusion and exclusion criteria[5–24]. The articles are summarized in Table 1. Research originated from 11 countries. The number of neurologically or musculoskeletally involved individuals treated on a standard tilt-table ranged from 1 to 38. Although individuals with stroke or brain injury were the most commonly studied, individuals with other nervous system problems (eg, spinal cord injury) were also investigated. Responses to a single session or multiple sessions were studied. Tilt-table standing sessions were sometime limited by orthostatic intolerance[15, 19], but sessions typically involved standing times of 20 to 40 minutes and table angles of 70° or more from horizontal. In 8 studies participants stood on a wedge or incline plates[6, 7, 9, 14, 16–18, 23].

The effect examined most consistently in the included articles was ankle dorsiflexion range of motion. Two studies reported ankle range of motion to increase over the course of a single standing session[17, 23]. Of studies focused on changes in ankle range of motion over multiple standing sessions, 4 reported a small increase in ankle dorsiflexion range of motion[9, 14, 20, 21] and 1 documented a small decrease[7]. Notably, however, the decrease was less in weightbearing limbs undergoing stretching than in non-weightbearing limbs not undergoing stretching[7]. Closely related to range of motion is ankle stiffness. Two studies showed resistance to passive ankle dorsiflexion to decrease significantly over the course of a tilt-table session[17, 18]. Odéen and Knutsson reported the decreases to be greater in patients who stood on the tilt table with the ankle dorsiflexed rather than plantarflexed[18].

The effects of tilt-table standing on positive motor signs varied. Of 6 studies grading spasticity using the Ashworth or Tardieu scales[5, 8, 14, 15, 19, 23], 2 noted an improvement (albeit not significant) after individual sessions of tilt-table standing[8, 23]. One of the 2 studies also produced improved performance on the pendulum test[8]. Bohannon, as well as Adams and Hicks, reported an improvement in extensor spasms after tilt-table standing[5, 8], but Adams and Hicks did not note improvement in flexor spasms or clonus after tilt-table standing[5]. Two investigative groups have described favorable changes in motor neuron excitability after a session of tilt-table standing, but only the changes reported by Tsai et al were significant[6, 23].

A broad array of other responses to tilt-table standing have been documented. Chief among these is the state of arousal and consciousness in patients with altered consciousness. Riberholt et al observed among patients with brain injury that tilt-table standing was associated with a significantly increased time with eyes open[19]. Krewer et al. reported significant increases in

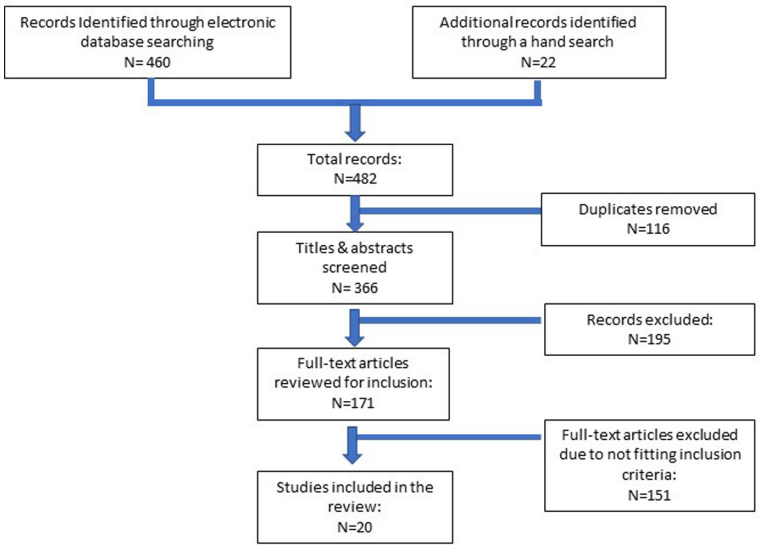

Fig. 1. Study flow diagram according to preferred reporting items for systematic reviews and meta-analyses (PRISMA).

Table 1. Summary of 20 articles included in systematic review

Study	Population	Intervention	Findings
Adams & Hicks[5]	Canadians with chronic spinal cord injury (n=7)	TT angle: greatest tolerated encouraged (maximum 80°, mean 68.6°). Time: 45 min maximum during 12 sessions over 4 wk Standing: bilaterally Other: body-weight supported treadmill training performed over another 4 wk	TT resulted in notable 0.9 point ↓ in extensor spasm severity after a single session & 1.0 point ↓ after 4 wk. No favorable Δ in MAS scores, flexor spasm severity, clonus severity, spasm frequency, spasticity impact, quality of life, or function.
Bakheit, et al.[6]	English with stroke & spasticity (n=66; 22/group) & healthy controls (n=21; 7/group)	TT angle: "vertical". Time: 20 min during 1 session. Standing: on footplate adjusted to maximum ankle dorsiflexion. Other: isokinetic or isotonic stretch.	Excitability of ankle plantarflexors as indicated by H_{max}:M_{max} & H-reflex latency ↓ but not SGNF post-stretch & 24 h post-stretch in TT or other groups.
Ben, et al.[7]	Australians with recent spinal cord injury (n=20)	TT angle: max tolerated, vertical encouraged Time: 30 min, 3 ×/wk for 20 wk. Standing: 1 lower limb on block and 15° wedge. Other: control limb unsupported (non-weightbearing)	Ankle dorsiflexion ↓ a mean 1° in weightbearing limb & ↓ 5° in nonweightbearing limb. Total proximal bone mineral density ↓ 0.06 g/cm^2 in the weightbearing and nonweightbearing limbs.
Bohannon[8]	American with chronic spinal cord injury (n=1)	TT angle: 80° Time: 30 min on 5 nonconsecutive days Standing: bilaterally. Other: not stated	Spasms & spasticity of knee extensors as documented by observation, pendulum test & MAS scores ↓ & transfers improved immediately after intervention but returned to baseline within 24 hours.
Bohannon, et al.[9]	Americans with assorted neurologic disorders: mostly stroke (n=20)	TT angle: 70° Time: 30 min on 5–22 days Standing: bilaterally on wedges Other: individually tailored treatments.	Mean passive ankle dorsiflexion ROM ↑ 8° (range 3° to 17°) over course of intervention.
Elliot, et al.[10]	English with brain injury (n=12)	TT angle: 85° Time: 20 min repeated over 1 wk Other: lying in bed	Highest rank & total number of behaviors of Wessex Head Injury Matrix during standing SGNF > during lying in bed.
Kim, et al.[11]	Korean's with stroke (n=34; 11–12/group)	TT angle: comfortable Time: 20 min/day for 6 wk. Standing: bilaterally (group 1), on more affected paretic lower limb (groups 2 & 3) Other: Group 2 rhythmically flexed and extended less affected lower limb. Group 3 performed task specific training of less affected upper limb. All groups received 30 min routine therapy.	Group 1: SGNF ↑ in paretic Fugl-Meyer upper limb score (3.4 points) but not Wolf Motor Function Test score (0.9 points) or grip strength. (0.9kg). Group 2: SGNF ↑ in paretic Fugl-Meyer upper limb score (9.2 points) & grip strength (4.7 kg) but not Wolf Motor Function Test score (0.8 points) Group 3: SGNF ↑ in paretic Fugl-Meyer upper limb score (10.5 points), Wolf Motor Function Test score (10.1 points), & grip strength (13.1 kg).
Kim, et al.[12]	Korean's with stroke (n=34, 11–12/group)	TT angle: Comfortable to maximum of 90°. Time: 20 min/day, 5 days/wk for 3 wk. Standing: bilaterally (group 2), on more affected paretic limb (group 3). Group 3 performed task oriented training. Other: All groups (including group 1 [control]) received 30 min routine therapy.	Group 2: SGNF ↑ in Barthel Index score (53.4 points), ↓ in National Institutes of Health Stroke Scale (score 4.9 points), ↑ in Fugl-Meyer score (11.9 points). Group 3: SGNF ↑ in Barthel Index score (59.9 points), ↓ in score 5.6 points), ↑ in Fugl-Meyer score (17.3 points).
Krewer, et al.[13]	Germans with severe disorders of consciousness (n=38, 19/group)	TT angle: 70° Time: 30 min, 3–4 sessions/wk for 3 wk. Standing: not specified Other: Erigo TT with robotic stepping device. therapist selected additional therapy.	Coma Recovery Scale scores ↑ SGNF from median 12 points @ baseline, to median 17 points @ 3 wk, to median 19 points @ 6 wk.

Table 1. Continued

Study	Population	Intervention	Findings
Leung, et al.[14]	Australians with traumatic brain injury (n=15)	TT angle: as upright as tolerated Time: 30 min, 3×/ wk for 6 wk, then 4 ×/wk Standing: bilaterally without wedge. Other: Experimental group supplemented TT standing with wedges & electrical stimulation to ankle dorsiflexors & splinting.	Mean passive ankle dorsiflexion ROM with 12 Nm stretching force ↑ 3° from −6° (baseline) to −3° (6 & 10 wk). Mean spasticity score (Tardieu) ↑ from 1 (baseline) to 3 (6 wk) & 2 (10 wk). Mean gait speed ↑ from 0.1 m/s (baseline) to 0.4 m/s (6 & 10 wk) Mean FIM gait score ↑ from 2 (baseline) to 3 (6 & 10 wk)
Luther, et al.[15]	Germans with subacute brain injury who were comatose or semicomatose (n=9)	TT angle: incrementally to 70°. Time: min not stated, 1 day Other: TT with stepping device	No SGNF ↑ in state of consciousness as measured by Coma Recovery Scale-Revised score during standing. Spasticity as measured by the MAS did not ↓ SGNF with standing.
Maynard, et al.[16]	English with chronic stroke (n=66; 22/ group) & healthy controls (n=21; 7/group)	TT angle: "vertical". Time: 20 min during 1 session. Standing: on footplate adjusted to maximum ankle dorsiflexion. Other: isokinetic or isotonic stretch	No SGNF improvement in any measured kinematic, kinetic, or spatio-temporal gait parameter immediately or 24 h after standing.
Ochi, et al.[17]	Japanese with subacute stroke (n=9)	TT angle: not stated Time: 10 min, 2 days/wk, for 2 wk. Standing: on incline plates. Other: Condition 1: no arm cranking. Condition 2: arm cranking. Routine rehabilitation.	Ankle dorsiflexion ROM ↑ SGNF by 8.9% & 11.7% on condition 1 days & 8.9% & 14.0% on condition 2 days. Ankle dorsiflexion stiffness ↓ SGNF by 8.0% & 7.9% on condition 1 days & 20.7% & 24.2% on condition 2 days. Gait velocity did not Δ SGNF on condition 1 or 2 days.
Odéen & Knutsson[18]	Swedes with chronic spinal cord injury (n=9)	TT angle: 85° Time: 30 min, 4 days Standing: with ankles dorsiflexed or plantarflexed 10°–15° Other: Ankle braced in dorsiflexion while patient supine	Mean resistance to ankle dorsiflexion at 0.25 cycle/s ↓ 15% (SGNF) in TT dorsiflexion condition and 11% in TT plantarflexion condition. Mean resistance to ankle dorsiflexion at 1.0 cycle/s ↓ 32% (SGNF) in TT dorsiflexion condition and 26% (SGNF) in TT plantarflexion condition.
Riberholt, et al.[19]	Danes with subacute aquired brain injury (n=16)	TT angle 80° Time: 20 min target during 1 session. Standing: no stipulation Other: Standard rehabilitation.	Time (66%) with eyes open during intervention SGNF > time (22.1%) before intervention. MAS was not SGNF different before & after intervention
Richardson[20]	English with subacute head injury (n=1)	TT angle: not stated Time: patient tolerance, 7 days Standing: less affected lower limb on box, more involved limb on footplate of TT table. Other: Standard rehabilitation.	Ankle dorsiflexion ROM during intervention period (mean −16°) < during preintervention baseline (mean −26.7°)
Robinson, et al.[21]	Australians with acute stroke (n=13)	TT angle: not stated Time: 30–40 min, 5 days/wk, for 4 wk Standing: less affected lower limb on box, more involved limb on footplate of TT. Other: night splint group. All received inpatient rehabilitation	Ankle dorsiflexion ROM ↑ 0.8° after 4 wk & 5.9° after 10 wk. Standing up ability (Motor Assessment Scale) ↑ mean 1.4 points after 4 wk & 2.2 points after 10 wk.
Toccolini, et al.[22]	Brazilians in intensive care units (n=23)	TT angle: progressively increased to 90° as tolerated. Time: 30 min as tolerated during multiple days. Standing: not specified	During tilting ↑ noted in Glasgow Coma Scale & Richmond Agitation-Sedation scale depending on tilt angle & session.

Table 1. Continued

Study	Population	Intervention	Findings
Tsai, et al.[23]	Taiwanese with chronic stroke (n=17)	TT angle: 85° Time: 30 min, 1 day Standing: ankles maximally dorsiflexed using wedges Other: Standard rehabilitation	Passive ankle dorsiflexion ROM ↑ SGNF (mean 5.1°) between pretreatment & posttreatment. MAS scores did not Δ SGNF. Motor neuron excitability (H/M ratio) ↓ SGNF (31.8%) after intervention; excitability (F/M) ratio ↑ SGNF (118%) after intervention). MAS scores for ankle plantarflexor muscles ↓ but not SGNF after treatment
Wilson, et al.[24]	English in vegetive or minimally conscious state (n=16)	TT: 90° as tolerated. Time: once	Number of behaviors of Wessex Head Injury Matrix during standing SGNF > during lying supine

@: at; Δ: change; ↓: decrease; ↑: increase; MAS: Modified Ashworth Scale; min: minutes; ROM: range of motion; SGNF: significant or significantly; TT: tilt table; wk: week.

Table 2. Quality rating of 20 articles according to PEDro scale

Reference	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Item 11	Sum
5	1	1	0	1	0	0	0	1	1	1	1	7
6	1	1	1	1	0	0	0	1	1	1	1	8
7	1	1	1	1	0	0	1	1	1	1	1	9
8	1	0	0	0	0	0	0	1	0	0	0	2
9	1	0	0	0	0	0	0	1	1	0	1	4
10	0	0	0	0	0	0	0	1	1	1	1	4
11	1	1	1	1	0	0	1	1	1	1	1	9
12	1	1	1	1	0	0	1	1	1	1	1	9
13	1	1	0	1	0	0	0	0	1	1	1	6
14	1	1	1	1	0	0	1	1	1	1	1	9
15	1	1	1	1	0	0	0	1	1	1	1	8
16	1	1	1	1	0	0	0	1	1	1	1	8
17	1	1	0	1	0	0	0	0	1	1	1	6
18	1	0	0	0	0	0	0	1	1	1	1	5
19	1	0	0	0	0	0	0	1	1	1	1	5
20	0	0	0	0	0	0	0	0	1	0	1	2
21	1	1	1	1	0	0	1	0	1	1	1	8
22	1	0	0	0	0	0	0	0	1	1	1	4
23	1	0	0	0	0	0	0	1	1	1	1	5
24	0	0	0	0	0	0	0	1	1	1	1	4

PEDRO items: 1. Eligibility criteria specified, 2. Participants randomly allocated to groups, 3. Allocation concealed, 4. Groups similar at baseline, 5. Participants blinded, 6. Therapy providers blinded, 7. Assessors blinded, 8. Key outcome obtained from >85% of allocated participants, 9. All participants received treatment or control condition as allocated, 10. Results of between-group comparison reported for at least one outcome, 11. Point and variability measures reported. Scoring: 0=no, 1=yes.

Coma Recovery Scale scores over a 3-week regimen of standing in patients in a vegetative or minimally conscious state[13]. Toccolini et al. found standing to be associated with improvements in the Glasgow Coma Scale and Richmond Agitation -Sedation scale scores[22]. Elliot et al. and Wilson et al. reported positive behavioral responses with standing according to the Wessex Head Injury Matrix[10, 24]. Luther et al did not find consistent improvement in Coma Recovery Scale scores with standing[15]. Among other responses to tilt table standing Ben et al found bone mineral density to decrease similarly in weightbearing and non-weightbearing limbs of patients with spinal cord injury in spite of their participation in a 20-week regimen of tilt-table standing[7]. Motor recovery, as reflected in various index scores (eg, Fugl-Meyer, Barthel, and NIH Stroke Scale), has been demonstrated (albeit not consistently) to improve following tilt-table standing[11, 12]. Although not consistently or significantly, specific activities such as walking[14, 16, 17], transferring[8], and standing up[21] have been shown to improve in some studies.

Table 2 summarizes the quality ratings of the reviewed articles. The scores ranged from 2 to 9 out of 11. The median score

was 7. Notably, no study met the blinding criteria for participants or therapy providers. All but 1 study specified eligibility criteria. Only 1 study failed to provide point and variability measures.

DISCUSSION

This systematic review was undertaken to determine if studies focused on neurologic or musculoskeletal effects of tilt-table standing support its use as a therapeutic intervention for adults. Relevant studies and sample sizes were limited in number, involved only patients with neurologic conditions, were diverse in regard to procedures, and demonstrated inconsistent findings.

The strongest evidence for tilt-table standing appears to be its association with small increases in ankle dorsiflexion range of motion over the course of a session or multiple sessions. The one study not finding such an increase did find the loss of range of motion to be less on the weightbearing limb. The use of a wedge may increase the effectiveness of tilt-table standing by reducing the plantarflexors' excitability and resistance to stretch. Notwithstanding this reduction in excitability and reports of some dramatic results in one case, evidence that tilt-table standing consistently results in reduced spasticity and spasms is mixed. We, like NG and King[25], conclude that studies addressing the effects of tilt-table standing on arousal are mostly positive but equivocal. Findings relative to standing and improvements in motor recovery and function are equivocal. The combination of purposive motor tasks with tilt-table standing may be augmentary. We found no evidence that tilt-table standing has a favorable effect on bone-mineral density.

Considering the findings and quality of the studies reviewed herein, an unqualified endorsement of tilt-table standing does not seem warranted. That noted, some individuals with neurologic disorders do appear to be responders to the intervention. Tilt-table standing therefore may be worth a trial with patients with specific problems. This is particularly the case if the tilt-table allows a therapeutic intervention (eg, prolonged high-load stretching of the ankle plantarflexor muscles) not otherwise practicable.

Further research into the value of tilt-table standing is clearly warranted. Such research could assist in the identification of patient and interventional variables affecting response to tilt-table standing. Among patient variables, degree of spasticity and time since onset might be important. Duration of standing might be a germane interventional variable if the intent is to affect ankle range of motion- particularly as no study we reviewed involved more than 40 minutes of standing per session and Tardieu et al have described 2 hours of stretching per day as inadequate to prevent progressive contracture[26].

Conflict of interest

None.

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