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Abstract

Objective

This investigation estimated the incremental cost-effectiveness of high-intensity training (HIT) compared with conventional physical therapy in individuals with subacute stroke, based on the additional personnel required to deliver the therapy.

Design

Secondary analysis from a pilot study and subsequent randomized controlled trial.

Setting

Outpatient laboratory setting.

Participants

Data were collected from individuals with locomotor impairments 1-6 months poststroke (N=44) who participated in HIT (n=27) or conventional physical therapy (n=17).

Interventions

Individuals performing HIT practiced walking tasks in variable contexts (stairs, overground, treadmill) while targeting up to 80% maximum heart rate reserve. Individuals performing conventional therapy practiced impairment-based and functional tasks at lower intensities (<40% heart rate reserve).

Main Outcome Measures

Costs were assessed based on personnel use with availability of similar equipment. Incremental cost-effectiveness ratios (ICERs) and cost-effectiveness acceptability curves were calculated for quality-adjusted life years (QALYs) derived from the Medical Outcomes Short Form-36 questionnaire and gains in self-selected speeds (SSSs).

Results

Personnel costs were higher after HIT (mean, $1420±234) vs conventional therapy (mean, $1111±219), although between-group differences in QALYs (0.05 QALYs; 95% confidence interval [CI], 0.0-0.10 QALYs) and SSS (0.20 m/s; 95% CI, 0.05-0.35 m/s) favored HIT. ICERs were $6180 (95% CI, −$96,364 to $123,211) per QALY and $155 (95% CI, 38-242) for a 0.1 m/s gain in SSS.

Conclusions

Additional personnel to support HIT are relatively inexpensive but can add substantial effectiveness to subacute rehabilitation. Future research should evaluate patient factors that increase the likelihood of improvement to maximize the cost-effectiveness of treatment post stroke.

Keywords
Cost-benefit analysis, Locomotion, Rehabilitation

List of abbreviations

CEA, cost-effectiveness analysis
CI, confidence interval
CONV, conventional
HIT, high-intensity training
ICER, incremental cost-effectiveness ratio
QALY, quality-adjusted life year
RCT, randomized controlled trial
SF-36, Medical Outcomes Survey Short Form-36
SF-6D, Short Form-6 dimension
SSS, self-selected speed
US, United States
VIEWS, Variable Intensive Early Walking Poststroke

The annual incidence of stroke in the United States (US) has approached 800,000, and with increased survival rates health care services are expected to reach $184 billion/y in the next decade.[1] After discharge from inpatient rehabilitation, for example, the cost of outpatient rehabilitation in the first year post stroke is approximately $11,689/patient.[2] The magnitude of stroke-related disability places a substantial burden on postacute rehabilitation services, leading to efforts to reduce costs through bundled payment models.[3] Consideration of the value of interventions, or cost-effectiveness, is critical given limited resources, although very little is known regarding the differential costs or effectiveness of rehabilitation strategies poststroke.

A primary goal for patients poststroke is to maximize locomotor capacity, typically defined as gait speed, which is strongly associated with endurance, community mobility, quality of life, and mortality.[4, 5, 6] High-intensity training (HIT) focused on stepping activities, during which therapists attempt to achieve higher heart rates and ratings of perceived exertion in their patients during training sessions, has been shown to improve gait speed and additional health outcomes in individuals poststroke compared with other interventions.[7, 8, 9] More recent data suggest HIT in variable contexts (treadmill, overground, stairs) can provide additional gains in balance and balance confidence.[10] Despite these benefits, clinical implementation of HIT may require additional personnel, particularly in more impaired individuals who require more physical assistance, which may pose a financial barrier for clinical implementation.[11]

Cost-effectiveness analysis (CEA) can be used to evaluate the relationship between the costs and outcomes of different interventions. Comparison of 2 different interventions using a CEA yields an incremental cost-effectiveness ratio (ICER), which is the difference in cost of 2 interventions divided by the difference in gains achieved with those interventions. Most CEAs include an estimate of health-related quality of life and may also include condition-specific measures of function or activity limitations.[12] To determine the effectiveness of HIT poststroke, the use of gait speed as an outcome may be relevant because of its meaningfulness to clinicians and patients, its association with other impairments, and its relationship to mortality.[4,5] Health-related quality of life is often measured by the Medical Outcomes Survey Short Form-36 (SF-36),[13] which can be used to calculate quality-adjusted life years (QALYs),[14] which is a generic measure of disease burden commonly used in economic evaluations. QALYs combines estimates of the quality of life (ie, morbidity) and quality of life (ie, mortality) into a single metric ranging from 0-1, where 1 is equivalent to 1 year of perfect health and 0 is equivalent to death. Using QALYs in CEAs allows comparison of results across cost-effectiveness studies.[15]

The goal of this study was to perform an economic analysis comparing the costs and relative effectiveness of HIT compared with conventional physical therapy for individuals with subacute stroke. Calculation of ICERs was performed for measures of health-related quality of life and gait speed, with variations in costs because of differences in personnel used during interventions. We hypothesized that HIT would be more cost-effective than conventional physical therapy for individuals with subacute stroke, despite additional personnel sometimes required. Such findings can estimate the relative value of these interventions to improve locomotor function early poststroke.

Methods

Data for this CEA were derived from the assessor-blinded Variable Intensive Walking Poststroke (VIEWS) randomized controlled trial (RCT)[8] and from a pilot cohort trial that served as the basis for the RCT.[16] Given nearly identical enrollment criteria and training protocols, data for those who completed HIT in the RCT (n=15) or the pilot study (n=12) were combined and compared with those who received conventional therapy (n=17). Power analyses to determine sample size for the RCT was calculated using data from the cohort trial, indicating that 32 participants (16 each group) were sufficient to observe differences in gait speed with 95% power.[8,16, 17, 18] In the RCT, additional differences were observed in SF-36 scores, and combined analyses with the cohort was expected to yield similar findings.

Inclusion criteria consisted of (1) history of unilateral stroke in the last 1-6 months; (2) aged 18-75 years; (3) ability to walk with moderate assistance or less (ie, perform at least 50% of work to ambulate), including the use of braces and devices as necessary, but at self-selected speeds (SSSs) <0.9 m/s; (4) ability to follow 3-step commands or Mini-Mental Status Examination >22/30; and (5) medical clearance to participate. Participants were excluded if they were unable to walk 150 ft independently prior to their stroke; had a history of additional neurologic disorders; presented with unstable cardiovascular, respiratory, or metabolic disease; or were unable to adhere to study requirements. Comorbidities for participants were described previously for the cohort study[16] and were similar in the RCT.[8] All participants provided written informed consent, and all procedures were approved by the local Institutional Review Board.

Interventions

The HIT protocol for the VIEWS and pilot study provided up to forty 1-hour sessions completed over 10 weeks.[8,16] Sessions included up to 40 minutes of stepping, with rest breaks as needed. The first 5-10 sessions focused on speed-dependent, forward treadmill walking, with body weight support provided as needed but reduced as quickly as possible. The remaining sessions were split between 25% forward treadmill walking, 25% variable treadmill walking (eg, multidirectional stepping, inclines, obstacles, leg weights, weighted vests), 25% overground walking (forward and variable walking practice), and 25% stair climbing over standard or rotating stairs (StairMaster[a]). Overground walking used either a gait belt or overhead suspension system for safety. Training sessions were supervised by a licensed physical therapist, with targeted intensities at 70%-80% of heart rate reserve or ratings of perceived exertion of 15-17.[19,20] Additional assistance was provided by a skilled assistant with an exercise science background or an unskilled assistant (rehabilitation aide or undergraduate assistant). Notably, the experimental HIT protocol did not focus on normalizing kinematics, and physical assistance was provided only as needed (ie, “assist-as-needed”) for limb advancement, propulsion, and maintaining upright posture to prevent loss of balance.

The conventional intervention in the VIEWS RCT was designed to be consistent with typical clinical practice for individuals with stroke.[8] Participants randomized to this intervention continued with their standard outpatient therapy services as prescribed. The characteristics of clinical physical therapy were extracted from medical records when possible. Components of conventional physical therapy included therapeutic exercises completed in a variety of positions (active and passive range of motion in seated or standing positions), overground and treadmill-based gait training with or without body weight support, and balance exercises. Conventional therapy sessions were supplemented by research physical therapists in an effort to achieve up to 40 sessions over 10 weeks similar to the experimental interventions. Tasks performed during conventional therapy were consistent with published observational data on the amount and types of activities performed during stroke rehabilitation[21,22] and with a targeted intensity range of 30%-40% heart rate reserve.[23, 24, 25]

Outcomes

Outcomes were collected at baseline, after up to 40 sessions during ≤10 weeks of training, and again at a 2- to 3-month follow-up. This analysis focuses on changes between the baseline and follow-up, representing the longer-term effects of the intervention.

Specific measures of effectiveness included changes in SSS and health-related quality of life. SSSs were assessed during 2 trials using a pressure-sensitive walkway (GaitMat[b]), with instructions to “walk at your normal, comfortable pace.” The minimally clinical important difference for SSS in people with subacute stroke has been estimated between 0.05-0.18 m/s,[26, 27, 28] although 0.1 m/s is a common threshold for a substantial minimal clinically important difference.[26]

Health-related quality of life was assessed using the SF-36 (version 2), with focus on the 8 subdomains, including Physical Function, Role-Physical, Pain, General Health, Vitality, Social Function, Role-Emotional, and Mental Health.[13] In addition, SF-36 scores were converted to the Short Form-6 dimension (SF-6D), which is a scoring algorithm used to compute QALYs.[14] The SF-6D uses specific questions from selected SF-36 subdomains (Physical Function, Role-Physical, Pain, Vitality, Social Function, Mental Function) and applies weights representing levels of health in different disease states that were obtained by surveying the general population.[14,29,30] These weights result in the calculation of QALYs ranging from 0 indicating death and 1 indicating 1 year in perfect health.

Direct costs of personnel for the experimental and conventional interventions were estimated from average salaries in 2016 US dollars. Personnel costs were estimated separately for patients with varied levels of walking deficits, given the potentially greater costs in those with more severe gait dysfunction. Participants with SSSs <0.2 m/s at baseline were thought to require greater staff resource utilization and benefit from more physical assistance (ie, manual or mechanical assistance).[31] Costs were therefore calculated separately for more (<0.2m/s) and less impaired participants (>0.2m/s). Costs were based on the hourly rate derived from annual salaries, exclusive of fringe benefits, for the physical therapist ($33.54/h US dollars), skilled assistants with a background in exercise physiology ($18.00/h), and unskilled assistants without similar educational background ($12.00/h). Total personnel costs were calculated using a microcosting approach, which is a cost-estimation method that involves direct enumeration of the time spent by personnel who treat specific patients and improves the precision of resource use and cost estimates.[32] Microcosting was conducted using training logs and clinical notes describing the level of assistance needed during training sessions for 6 participants who received HIT and 6 who received conventional interventions, with equal numbers of those with SSS < and > 0.2 m/s. Although participants with SSS <0.2 m/s typically used more physical assistance because of severity of impairments, patients with SSS >0.2 m/s could require additional assistance needed for equipment (ie, overground wheeled harness system) or when a therapist was supervising a nonclinician while documenting therapy notes or assisting another participant.

Costs were averaged within each intervention and separately for those with SSS < and > 0.2 m/s and then applied to the other participants within each intervention and speed subgroup. Because the interventions were provided at the same locations with similar equipment and differences only in intervention strategies, indirect costs and equipment costs were considered equivalent across groups. In CEAs, costs and health outcomes that are recorded over multiple years are typically discounted to account for the fact that people have a preference to experience immediate health effects and delay costs until a later date. However, the intervention and follow-up in this study occurred within a 1-year time frame so there was no need to discount costs and effects.

Statistical analyses

Analyses were performed in SAS 9.4[c] and MATLAB.[d] Descriptive statistics and independent *t* tests were used to compare change from baseline to follow-up in SF-36 subdomain scores, SF-6D, SSS, and costs. Independent *t* tests comparing the changes in outcomes between the 2 groups were used because of the exploratory nature of the analyses rather than more rigorous models that may increase type I error.

The cost-effectiveness of HIT was conducted from the provider perspective and calculated using 2 separate effectiveness measures. An incremental ICER was determined as the difference in mean costs between HIT and conventional (CONV) therapy divided by the differences in mean changes (ie, effects) in SSS and QALYs after each intervention using the following formulas:

(1) $\text{ICER}_{\text{SSS}} = (\text{cost}_{\text{HIT}} - \text{cost}_{\text{CONV}})/(\Delta\text{SSS}_{\text{HIT}} - \Delta\text{SSS}_{\text{CONV}})$

(2) $\text{ICER}_{\text{QALY}} = (\text{cost}_{\text{HIT}} - \text{cost}_{\text{CONV}})/(\Delta\text{QALY}_{\text{HIT}} - \Delta\text{QALY}_{\text{CONV}}$

The $\text{ICER}_{\text{QALY}}$ was calculated on the costs associated with a change in QALYs that is associated with 1 year of perfect health, whereas the ICER_{SSS} was calculated based on a change of 0.1 m/s because this value represents the threshold for a substantial MCID in SSS.[26]

Calculations of ICERs generate point estimates (ie, mean differences) without providing estimates of uncertainty (ie, variability) that can facilitate interpretation of CEA findings. Uncertainty in calculated ICERs was identified in 2 ways. We first performed nonparametric bootstrapping of cost and effect pairs with 10,000 replications, which were used to determine the 95% confidence intervals (CIs) of resampled ICERs defined as the 2.5th and 97.5th percentile, consistent with published CEAs.

The ICER and the resampled estimates can be depicted visually on a cost-effectiveness plane plotting differences in the effectiveness of each intervention (x-axis, fig 1) against differences in intervention costs (y-axis, fig 1). The cost-effectiveness plane is divided into 4 quadrants through the origin, and each quadrant has different implications. Interventions with ICERs in the bottom right quadrant are more effective and less costly than the comparator and always considered more cost-effective. Conversely, ICERs in the top left quadrant indicate the intervention is less effective and more costly than the comparator, and consequently never more cost-effective. If ICERs fall in the top right quadrant, indicating the intervention is more costly and more effective, or bottom left, indicating the intervention is less costly and less effective than the comparator, then the relative magnitude of costs and effectiveness between the intervention and comparator should be considered.

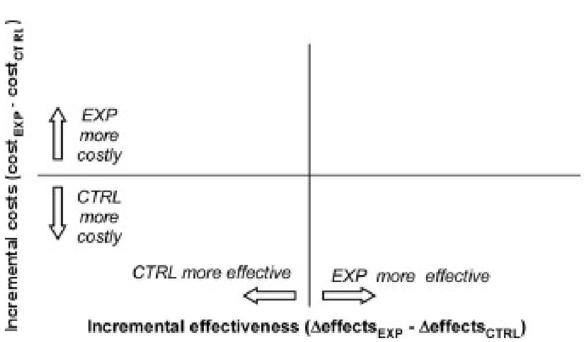

Fig 1. Schematic of a cost-effectiveness plane depicting difference in effects (x-axis) and difference in costs (y-axis) between experimental or control intervention. ICERs plotted in the different quadrants depicts different relative cost-effectiveness. Abbreviations: CTRL, control; EXP, experimental.

From these data, cost-effectiveness acceptability curves were constructed to illustrate the probability of cost-effectiveness relative to a decision- or policymaker's potential willingness to pay for the intervention. This probability is identified as the proportion of resampled ICERs that fall below and to the right of a line passing through the origin, with a slope (ie, cost/effectiveness) equivalent to the willingness-to-pay threshold. Systematic manipulation of potential willingness-to-pay thresholds (ie, slopes) revealed different probabilities on each side of these lines, with a probability of 50% considered an acceptable risk.[33] Cost-effectiveness acceptability curves plot the different willingness-to-pay thresholds (x-axis) to the probability of cost-effectiveness (y-axis).

Results

Table 1 describes the 44 participants who were included in the analyses, including 27 participants provided HIT in the pilot study (n=12) or the RCT (n=15) and 17 participants who received conventional interventions. Nearly 40% of participants presented with baseline SSS <0.2 m/s (6/17 provided conventional therapy, and 10/27 provided HIT) (see table 1).

Table 1. Participant characteristics

	Conventional	**HIT**	
Characteristics	**VIEWS RCT**	**Pilot Study**	**VIEWS RCT**
n	17	12	15
Age (y), mean ± SD	60±9.2	52±13	57±12
Sex (male), n (%)	12 (71)	8 (67)	12 (80)
Time poststroke (mo), mean ± SD	2.9±1.4	3.2±1.8	3.7±1.8
Side of paresis (left), n (%)	12 (71)	4 (33)	9 (60)
Ankle foot orthosis, n (%)	14 (82)	4 (33)	11 (73)
Assistive device, n (%)	14 (82)	9 (75)	13 (87)
<0.2 m/s, n (%)	6 (35)	4 (33)	6 (40)

Intervention costs were calculated based on the salaries of the personnel who provided the training and total number of staff required for each participant (table 2). Details of the approximate time of different personnel used to assist with the training of 6 participants in each training group (3 <0. 2m/s and 3 >0.2m/s) are provided in table 2. Personnel costs for HIT averaged $1695 and $1257 for those with SSS <0.2 m/s and >0.2 m/s, and conventional costs were $1386 and $961, respectively. On average, personnel costs were $309 higher for HIT than for conventional therapy ($1420±234 vs $1111±219, respectively) (table 3).

Table 2. Personnel assistance required to complete intervention by identifying minutes and sessions required by different staff skill level

SSS (m/s)	**Sessions**	**Min/Session with Skilled Assistant**		**Min/Session with Unskilled Assistant**		**Estimated Costs ($)**	**Average Costs ($)**
		Min	**Sessions**	**Min**	**Sessions**		
HIT <0.2 m/s							
0.00	40	20	5	60	35	1992	
0.17	40	15	20	0	0	1402	1695
0.13	34	0	0	20*	5*	1693	
HIT >0.2 m/s							
0.46	40	15	19	0	0	1399	
0.90	32	15	12	0	0	1109	1257
0.56	36	15	19	0	0	1265	
Conventional <0.2 m/s							
0.16	40	0	0	0	0	1342	
0.06	40	0	0	20	40	1501	1386
0.08	39	0	0	0	0	1308	
Conventional >0.2 m/s							
0.82	25	0	0	0	0	829	
0.47	34	0	0	0	0	1140	961
0.53	27	0	0	0	0	906	

NOTE. 1 participant had 2 phases of training requiring different levels of assist (first 5 required less assistance with treadmill training, next 29 required more unskilled assistance with overground walking.

*Assistance was only provided during specific sessions.

Table 3. Mean scores and differences between groups in clinical and quality of life outcomes.

	HIT, Mean ± SD		**Control, Mean ± SD**		**ΔFollow-up-Baseline (95% CI)**
Variables	**Baseline**	**Follow-up**	**Baseline**	**Follow-up**	
Average cost ($)	1420±234		1111±219		309 (168-450)
Physical Function	30±19	48±19	29±24	38±21	9.2 (−3.2 to 22)
Role-Physical	29±22	48±24	40±26	42±28	17 (1.8 to 32)*
Pain	20±45	23±47	67±24	65±26	4.5 (−9.5 to 19)
General Health	60±18	60±24	66±17	71±17	−4.0 (−14 to 6.4)
Vitality	57±25	64±22	65±20	69±25	3.0 (−11 to 17)

Social Function	48±14	53±16	44±18	48±11	0 (−10 to 10)
Role-Emotional	65±32	74±28	73±29	70±32	12 (−6.0 to 30)
Mental Health	51±19	54±18	63±12	63±16	2.6 (−5.7 to 11)
SF-6D index	0.61±0.12	0.66±0.11	0.65±0.12	0.65±0.14	0.05 (0.00-0.10)*
Incremental cost per ΔQALY=$6180 (−96,364 to 123,211)					
SSS (m/s)	0.32±0.26	0.65±0.38	0.35±0.24	0.48±0.33	0.20 (0.05-0.35)*
Incremental cost per 0.10 m/s ΔSSS=$155 (38-242)					

NOTE. SF-36 data were missing for 1 patient in the control and 3 in the experimental group. ICERs presented with 95% CI from bootstrapped data, whereas SF-36, SSS, and costs are summarized from actual data.

*Significant differences between experimental and control groups.

Consistent with previous findings, significantly greater gains in SSS were observed after HIT vs conventional therapy, with 0.2 m/s difference in changes in SSS (see table 3). In addition, changes in SF-36 subdomains and SF-6D scores are presented in table 3. Significant differences were observed for the Role-Physical SF-36 subdomain, with large but nonsignificant differences in Physical Function and Role-Emotional. Conversion of scores to the SF-6D also revealed significant differences between training groups (see table 3).

ICERs were calculated based on the average costs and changes in SSSs and QALYs with determination of uncertainty using bootstrapping techniques. The ICER for incremental gains in SSS with HIT compared with conventional therapy was calculated as $155 for a 0.1-m/s gain, with 95% CI of $38-$242, and the ICER per QALY was $6180 (95% CI, −$96,364 to $123,211). Figure 2 depicts 1000 resampled data sets on cost-effectiveness planes for both SSS (see fig 2A) and QALYs (see fig 2B), indicating nearly all SSS data in the top right quadrant, with greater variability for QALYs.

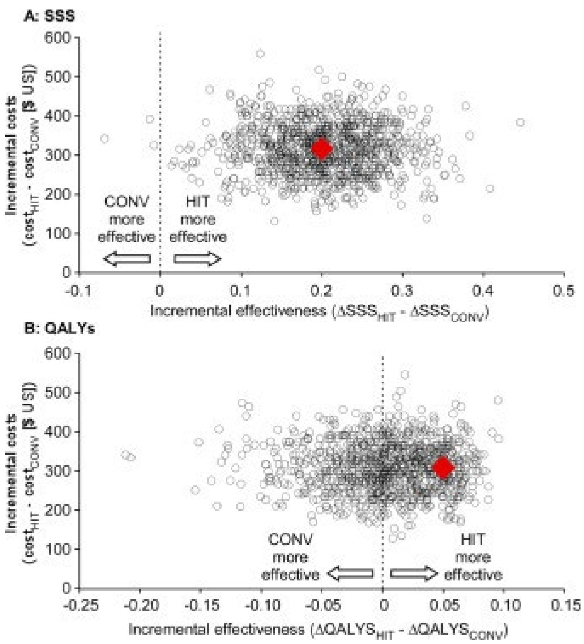

Fig 2. Cost-effectiveness planes for SSS (A) and QALYs (B). Each plane depicts 1000 bootstrapped samples (open circles) with the average ICER for SSS and QALYs also identified (red diamond).

Cost-effectiveness acceptability curves identified the proportion of ICER estimates that were cost-effective at different thresholds for willingness to pay (fig 3).[34] At $155 willingness to pay per 0.1 m/s change in SSS, HIT had a 50% probability of being cost-effective, and the probability of HIT being cost-effective was >90% if willingness to pay was at least $300 per 0.1 m/s change in SSS. At a willingness to pay of $30,000-50,000 per QALY, HIT had a 48%-52% probability of being cost-effective (see fig 3B).[27]

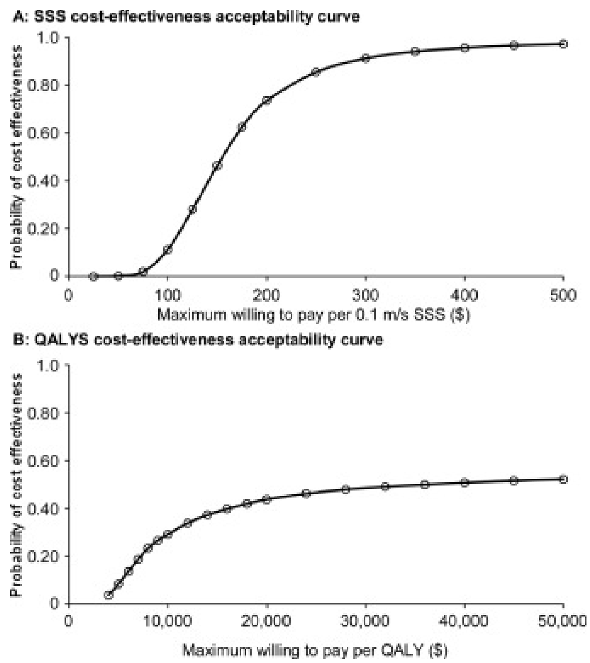

Fig 3. Cost-effectiveness acceptability curves indicating probabilities of HIT as a cost-effective strategy based on a threshold of maximum willingness to pay for both SSS (A) and QALYs (B).

Discussion

This exploratory CEA suggests that higher personnel costs for HIT performed in variable contexts may be cost-effective compared with conventional interventions given the significantly greater gains in SSS and QALYs at the follow-up evaluation. The relatively high probabilities of cost-effectiveness for gains in SSS and QALYs support consideration of hiring additional personnel to assist therapists to perform HIT interventions. These considerations of value for postacute rehabilitation interventions are critical to both maximize outcomes while minimizing costs in preparation for value-based payment policies.

Both SSS and QALYs derived from specific SF-36 scores were used in these analyses, which have been presented previously.[8,16] Calculation of the different subdomains has not been presented, revealing significant changes in Role-Physical, with large nonsignificant improvements in Physical Function and Role-Emotional. Despite smaller changes in other subdomains, gains in Physical Function and Role-Physical appeared to contribute to the significant gains in SF-6D that allowed comparisons with other CEAs. For example, the estimated ICER of $6180 for a 1-unit increase in QALY (1y of perfect health) is well under the $50,000/QALY willingness-to-pay threshold associated with “good value” for interventions, although substantial variability led to probabilities ∼50% at >$30,000.[35] The relatively low ICER with wide 95% CIs margins are similar to other therapy interventions.[36,37] For example, upper limb robotic therapy is associated with similar changes in QALYs (∼0.05), with an average cost savings of $1267 with bootstrapped ICER 95% CIs of −$450,255 to $393,356.[37] As a comparison, the use of tissue plasminogen activator within <3 hours of ischemic stroke results in a gain of 0.39 QALYs and lifetime cost-savings of $25,000 compared with people who do not receive tissue plasminogen activator.[38]

To our knowledge, this is the first use of estimated cost-effectiveness between different interventions poststroke for changes in SSS, which is related to multiple measures of mobility, quality of life, and mortality.[4,5] The 0.1-m/s increment in SSS was chosen as a standard minimal clinically important difference of locomotor function,[26] with an ICER of $155 per 0.1 m/s gain and a >90% probability of cost-effectiveness if stakeholders are willing to pay $300 (see fig 3). Others have previously argued that >50% probability of cost-effectiveness denotes a “winner” when a decision must be made across a population,[33] in which case $155 is the willingness-to-pay threshold. The question of “what is the worth of a 0.1-m/s gain in SSS?” should likely be discussed by decision- or policymakers when clinically relevant measures are used in CEAs.

An important caveat of the present study relies on the understanding of the strategies applied during conventional and experimental (HIT) protocols. Conventional therapy used traditional interventions, including impairment-based or functional exercises as detailed in observational studies, rehabilitation texts, and educational programs.[23,39,40] Additional equipment, such as motorized treadmills and weight support systems, were available at all conventional and experimental training sites during all interventions. However, the HIT paradigm also relied on relatively low-cost strategies, including use of gait belts, orthotics, cones, stop watches, and stairs, with no virtual reality or robotic systems used, thereby minimizing the costs associated with equipment. Use of various heart rate monitors, pulse oximeters, or sphygmomanometers may add additional costs but are considered necessary to ensure patient safety during training. Notably, lower-resourced clinics outside academic medical centers may not have motorized treadmills or body weight support systems, although the average cost of a treadmill and maintenance expenses per use when used in a busy clinic are estimated to be less than $10 per training session.[41] Although there were additional personnel during HIT, this intervention used assistants sparingly because of its focus on “assist-as-needed” rather than normalizing kinematics. Therefore personnel were likely less costly than those in previous studies that reported financial feasibility even when requiring 1-4 personnel to assist with stepping.[36] Combined with earlier data published on the efficacy of HIT with variable stepping contexts and the pragmatic assistance-as-needed approach, the present findings support the integration of HIT into clinical settings, particularly when equipment such as treadmills and harness systems are available.[8,16]

Alternative strategies to reduce personnel costs may be used, although their efficacy can be limited and equipment costs may be increased. For example, substantial investment in engineered technologies and robotic devices to assist in repetitive stepping practice have demonstrated some positive results,[42, 43, 44] although other research and clinical practice guidelines suggest such devices are not effective when compared with alternative strategies.[45, 46, 47] Some of these devices could be considered budget neutral compared with therapist-assisted training with multiple therapists to normalize kinematics.[37] However, providing assist-as-needed strategies[48] has been found to result in greater gains than robotic-assisted training in subacute and chronic stroke, and the reduced personnel would likely result in greater cost-effectiveness.[45,46] Further research should be directed toward understanding the relative cost-effectiveness of these engineered technologies compared with HIT in variable contexts.

Study limitations

This post hoc analysis should be interpreted with caution. First, the present study focuses solely on personnel costs, assuming the therapists have similar equipment with which they can choose to increase the cardiovascular intensity of stepping practice. However, HIT can be performed overground and on stairs, and previous studies have detailed positive findings of high-intensity interventions provided without treadmills.[49,50] Indeed, the use of specific strategies, rather than the equipment itself, differentiates the experimental and conventional strategies. A further limitation is the incorporation of personnel costs based on 2016 salaries, which may not apply to other institutes at this time. Costs may likely be higher but would be limited to increased salaries of skilled and unskilled assistants because physical therapist costs are similar with both HIT and conventional interventions. Another limitation may be generalizability of the findings because we included the cohort (case series) data with the RCT. Although the sample studied here is relatively small, we combined data from these 2 studies to mitigate limitations associated with having a small RCT sample when estimating the effectiveness of HIT. However, there is substantial variability within the experimental cohort. Nonetheless, this exploratory CEA provides valuable data to support future cost-effectiveness studies of intense rehabilitation interventions, which may wish to attend to the amount of assistance required and the characteristics of the facilities.

Conclusions

The findings of the present study suggest greater costs and effectiveness of HIT compared with conventional training, such that the relative value of HIT warrants greater use in the clinical setting. Future research should be directed toward understanding the effectiveness and relative costs of providing HIT in larger patient cohorts.

Suppliers

a. StairMaster; StairMaster.
b. GaitMat; Equitest.
c. SAS 9.4; SAS Inc.
d. MATLAB; MathWorks.

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