Spine

HEALTH SERVICES RESEARCH

Are Nonpharmacologic Interventions for Chronic Low Back Pain More Cost Effective Than Usual Care? Proof of Concept Results From a Markov Model

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Study Design. Markov model.
Objective. Examine the 1-year effectiveness and cost-effectiveness (societal and payer perspectives) of adding nonpharmacologic interventions for chronic low back pain (CLBP) to usual care using a decision analytic model-based approach.
Summary of Background Data. Treatment guidelines now recommend many safe and effective nonpharmacologic interventions for CLBP. However, little is known regarding their effectiveness in subpopulations (e.g., high-impact chronic pain patients), nor about their cost-effectiveness.
Methods. The model included four health states: high-impact chronic pain (substantial activity limitations); no pain; and two others without activity limitations, but with higher (moderate-impact) or lower (low-impact) pain. We estimated intervention-specific transition probabilities for these health states using individual patient-level data from 10 large randomized trials covering 17 nonpharmacologic therapies. The model was run for nine 6-week cycles to approximate a 1-year time horizon. Quality-adjusted life-year weights were based on six-dimensional health state short form scores; healthcare costs were based on 2003 to 2015 Medical Expenditure Panel Survey data;

and lost productivity costs used in the societal perspective were based on reported absenteeism. Results were generated for two target populations: (1) a typical baseline mix of patients with CLBP (25% low-impact, 35% moderate-impact, and 40% high-impact chronic pain) and (2) high-impact chronic pain patients.
Results. From the societal perspective, all but two of the therapies were cost effective (<$50,000/quality-adjusted life-year) for a typical patient mix and most were cost saving. From the payer perspective fewer were cost saving, but the same number was cost-effective. Assuming all patients in the model have high-impact chronic pain increases the effectiveness and cost-effectiveness of most, but not all, therapies indicating that substantial benefits are possible in this subpopulation.
Conclusion. Modeling leverages the evidence produced from clinical trials to provide more information than is available in the published studies. We recommend modeling for all existing studies of nonpharmacologic interventions for CLBP.
Key words: acupuncture, chronic low back pain, cost-effectiveness, exercise, high-impact chronic pain, Markov model, massage, nonpharmacologic interventions, spinal manipulation, yoga.
Level of Evidence: 4
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Many safe and effective nonpharmacologic interventions for chronic low back pain (CLBP) are recommended in treatment guidelines.[1–4] Recommended interventions include therapies such as acupuncture, mindfulness-based stress reduction, and yoga. Although these nonpharmacologic therapies have been available to the public for years, many are not part of the healthcare system, prescribed by physicians, nor generally covered by third-party payer plans. In addition, although all recommended therapies are effective, it is unknown whether

some are more effective than others, especially for certain patient groups, and their impact on costs.

The effectiveness of each recommended nonpharmacologic therapy is supported by systematic reviews and meta-analyses over dozens of studies.[3,5–7] In a few cases, these studies directly compare two or more of the recommended therapies, but usually each therapy is studied as adjunct to usual care and compared to usual care alone. Network meta-analysis (aka multiple or mixed treatment comparisons) is one technique that goes beyond traditional pairwise meta-analysis to allow comparisons and ranking between therapies that were not directly compared in clinical trials.[8–11] However, the application of this technique requires that each therapy be directly compared to at least one comparator also used in another trial, and thus allowing indirect comparisons. Because of its common use, the logical common comparator for most therapies is usual care. However, the substantial variation across studies in what constitutes usual care and the lack of other common comparators lowers the reliability of network meta-analysis results.[8]

Decision analytic modeling is another method to synthesize evidence and compare across therapies.[12,13] Modeling allows consistent inputs to be used across interventions, the simulation of experiments such as head-to-head trials, and the inclusion of economic outcomes even when they were not included in the original studies.[12,14]

Because each therapy is studied as an addition to usual care, its likely incremental effects in other healthcare settings can be estimated by comparing to the version of usual care used in the trial.

The 2016 US National Pain Strategy[15] placed a focus on those with high-impact chronic pain defined as that "associated with substantial restriction of participation in work, social, and self-care activities for 6 months or more."[15, p. 11] Studies have used different algorithms to identify those with high-impact chronic pain,[16–21] and to demonstrate their significantly higher healthcare costs, lower quality of life, worse mood, and increased absenteeism.[18–27] Nevertheless, studies of interventions for chronic pain still report results based on full samples (*e.g.*, average change in symptoms or percent of patients who improve). To better understand chronic pain, better compare study results, and better target interventions, we need to move beyond simple duration of pain definitions (*e.g.*, 3+ months) to identify meaningful chronic pain subtypes. Modeling can then be used to balance the baseline subtype mix of patients across studies and estimate differential treatment effects by subtype (*e.g.*, chronic pain impact level).

Although several economic evaluations of nonpharmacologic therapies for CLBP have been published,[28–34] because economic outcomes are not generalizable across settings,[35] each study's results can only provide useful information about cost impacts in its country and setting. Modeling is used to adjust inputs and assumptions to adapt study results to other settings.[36]

This study presents the results of a proof-of-concept modeling effort that used individual patient-level data from 10 randomized studies and the categorization of these study's participants by chronic pain impact level to estimate the effectiveness and cost-effectiveness of adding recommended nonpharmacologic therapies for CLBP to usual care.

METHODS

This study used a Markov simulation model to compare the effectiveness and cost-effectiveness of a set of recommended nonpharmacologic therapies for CLBP. This modeling effort was part of a larger study examining the appropriateness of spinal mobilization and manipulation (M/M) for CLBP.[37,38] This model was built to provide information to expert panels on the cost-effectiveness of M/M as compared to other nonsurgical interventions for CLBP to see if this information would change their original safety and effectiveness-based ratings of the appropriateness of M/M. To ensure face and construct validity[39] and maximize the model's usefulness and relevance,[40] we built it with the input of an expert in the use of M/M for CLBP (E.L.H.) and a nine-member panel of expert representatives of the types of policy makers who could use the model's results.

The model included transition probabilities that moved a hypothetical cohort of patients between four defined health states every 6 weeks for just over a year (Figure 1). One health state was defined as high-impact chronic pain (individuals with substantial activity limitations)[15]; one as a healthy, no pain state; and two others were without activity limitations, but with higher (moderate-impact) or lower (low-impact) pain. We estimated intervention-specific transition probabilities for these health states using individual patient-level data from the 10 trials[41–50] covering 17 nonpharmacologic therapies. Trials of M/M and other common nonpharmacologic interventions for CLBP were chosen following these inclusion criteria: large sample sizes (*e.g.*, at least 50 per arm), all (or most) of the subjects experienced CLBP (≥3 months' duration), at least 6 months follow-up, and US, Canada, or UK based for ease of acquisition and similar usual care. We also required that the study measured variables that were useful for the estimation of chronic pain impact levels (*i.e.*, measures of pain, function, and quality of life). Four trial datasets[41–43,48] contained direct measure of chronic pain impact level using the Graded Chronic Pain Scale[20,25,27,51,52]: low-impact (grade I), moderate-impact (grade II), and high-impact (grade III/IV) chronic pain. Chronic pain impact levels were estimated for the other datasets using logistic models with excellent predictive power[53] using patients' pain intensity, Roland-Morris Disability scores,[51,54] and short form (SF)-12[55] or SF-36[56] items as independent variables. Details on the datasets acquired and the identification of each patient's health state at baseline and over time are provided elsewhere.[53]

Each health state was assigned a quality of life or quality-adjusted life-year (QALY) weight (calculated as the SF-6D[57,58] score over 6 weeks) and 6-week costs (Table 1). The healthcare costs were estimated from 2003
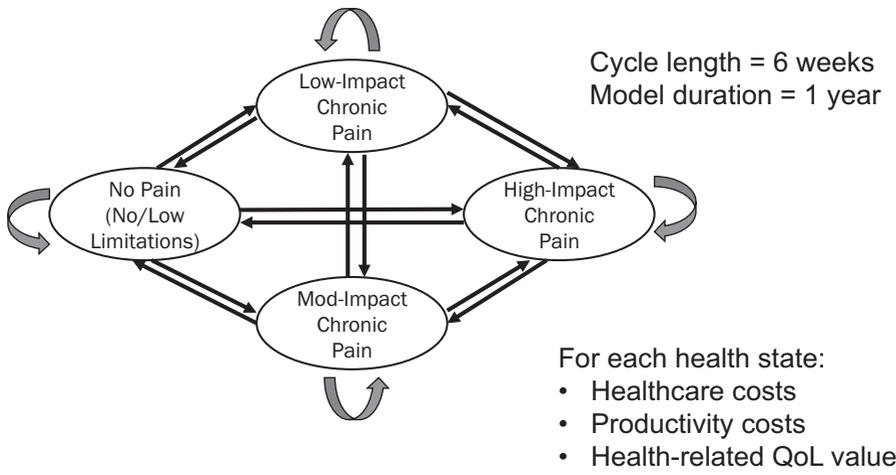
Figure 1. Schematic of the Markov model structure. Ovals represent the four health states: high-impact chronic pain (substantial activity limitations); no pain; and two without activity limitations, but with higher (moderate-impact) or lower (low-impact) pain. Arrows represent the probability of transitions within and between health states and each therapy has its own set of transition probabilities. Patients begin in one of the three right-hand side health states and can transition to other health states in 6-week cycles.

to 2015 Medical Expenditure Panel Survey (http://meps.ahrq.gov/mepsweb/) data,[59] and represent average US-based 2015 healthcare costs associated with back pain. Estimates of absenteeism and utility were taken from trial data as described elsewhere.[53] Productivity loss was estimated based on patient-reported absenteeism for those employed, and valued using the human capital approach[60] at the US Bureau of Labor Statistics June 2015 national average employer cost of employee compensation for civilian workers of $33.19.[61] The simulation tracked a cohort of hypothetical new CLBP patients over nine 6-week cycles and summed QALY gains and costs to yield estimated 54-week health and cost outcomes.

The resources used in the delivery of the nonpharmacologic interventions and usual care were captured from the information available in each study's publications. The unit costs for each type of practitioner used were estimated as the average (after trimming the top and bottom 5%) of the costs per visit available in the Medical Expenditure Panel Survey. The full list of unit costs and their sources, the information available from each study, and the resulting treatment costs for each therapy are shown in Appendix, http://link-s.lww.com/BRS/B434.

ANALYSIS

For each therapy, the model projected progression across health states based on estimated transition probabilities, that is, the likelihood that an individual receiving that intervention will stay in their present state or move to another health state for the next 6-week cycle. Transition probabilities were estimated based on actual patient progression through health states in trial data. Nine trials measured outcomes over 1 year and the other[50] went out 6 months. This study's 6-month outcomes were held constant to 12 months based on the 6- to 12-month results of another yoga study.[62]

Health States	Back-Related Healthcare Costs*	Productivity Loss (From Absenteeism)[†]	Utilities (Measure of Health-Related Quality of Life)[‡]
No pain (no-to-low disability)	$ –	$3.76 ($2.66)	0.806 (0.004)
Low-impact chronic pain (low pain, low activity limitations)	$265.34 ($37.89)	$31.90 ($14.75)	0.763 (0.003)
Moderate-impact chronic pain (high pain, low activity limitations)	$496.30 ($56.48)	$47.55 ($9.61)	0.704 (0.006)
High-impact chronic pain (substantial activity limitations)	$689.91 ($54.38)	$288.93 ($51.88)	0.610 (0.007)

TABLE 1. Model Inputs: 6-Week Healthcare Costs (2015$) Productivity Loss (2015$), and Utilities Used to Calculate Quality-Adjusted Life-Years, Mean (SE)

*Estimated from 2003 to 2015 Medical Expenditures Panel Survey data. Societal perspective (includes healthcare costs paid by patients).

[†]Patient self-report absenteeism from the Hurwitz et al, 2002, study. Valued using the Bureau of Labor Statistics 2015 Employer Cost of Employee Compensation of $33.19 per hour.

[‡]Utilities (six-dimensional health state short form [SF-6D] scores) from the Cassidy et al, 2005, study. These amounts are multiplied by 6/52 to generate the quality-adjusted life-years (QALYs) added for each 6-week period.

Because each study's data collection occurred at different intervals, each study's empirical transition probability matrix was first converted into a weekly matrix by translating the empirical probabilities into weekly rates and then converted into 6-week cycles that could be used in the model. We defined a typical mix of CLBP patients as having the following proportions at baseline: 25% low-impact, 35% moderate-impact, and 40% high-impact chronic pain. These proportions reflect the average baseline mix of patients in the trials used in the model.[53]

The Markov model was run for nine 6-week cycles to approximate a 1-year (54 weeks) time horizon. As individuals cycled through the health states they accumulated healthcare costs, productivity loss, and QALYs according to the values in Table 1. The model is probabilistic in that the effect of the uncertainty (SEs) of the mean input parameters, and of our estimation of the transition probabilities, was reflected in measures of output uncertainty (e.g., confidence intervals around 1-year costs and QALY gains).[63] Because each intervention was studied as adjunct to usual care, incremental costs and effects for each therapy were calculated net of each study's version of usual care. The model allows estimation of relative effectiveness and cost-effectiveness across all therapies. However, because these therapies are not equally available and accessible,[64] and may not be equally acceptable to patients, our main results are presented for each therapy compared to usual care, and comparisons across all therapies are presented in the Appendix, http://links.lww.com/BRS/B434. Two studies did not include a usual care arm.[48,65] For each we assigned two US-based usual care options based on the need for similar data collection schedules (see Appendix for details, http://links.lww.com/BRS/B434).

Finally, we performed tests of internal consistency (do model input changes have predictable effects on outputs) and external consistency (comparing model results to that shown in published studies).[40] The Markov models were run using TreeAge Pro 2018 R2.1, Williamstown, MA, and other analyses used Microsoft Excel 2016, Redmond, WA.

RESULTS

Table 2 gives the model's incremental results compared to usual care for the societal and payer perspectives for a typical mix of chronic low-back pain patients. Table 3 shows the same information assuming all patients start with high-impact chronic pain. Figure 2 graphically displays the incremental point estimates for a typical mix of patients from the societal perspective. The 0, $0 point represents usual care and points below $50,000/QALY (a commonly defined threshold[66]) are generally considered cost effective. As can be seen, all interventions but two (traditional Chinese acupuncture and spinal manipulation assuming the same usual care) are cost-effective, many therapies have similar effectiveness and cost-effectiveness, and most showed cost savings from the societal perspective. The distance between the two versions of each intervention with assigned usual

care arms indicates the sensitivity of interventions' impacts to underlying usual care.

Yoga had the largest effects and cost savings. In fact, in terms of relative cost-effectiveness yoga was dominant—that is, had lower costs and higher QALY gains than any other intervention (see Appendix, http://links.lww.com/BRS/B434). When costs are included from the payer perspective the same interventions are cost-effective, but fewer are cost saving.

When we assume all patients start with high-impact chronic pain, the results are more favorable for many therapies. However, some therapies have less favorable results: cognitive behavioral therapy (CBT) educational program, exercise, multidisciplinary care, and Traditional Chinese medicine acupuncture, all had smaller QALY gains and higher costs in the high-impact group than with a typical mix of patients.

All internal consistency checks were successful. Model outputs responded as expected to variations in intervention costs, other healthcare costs, utilities, and transition probabilities. The Appendix, http://links.lww.com/BRS/B434 contains the results of two tests of external consistency. Even though complete consistency is not expected since the model balanced baseline patient mixes and estimated QALYs, the model's ranking of within-study functional effectiveness across arms was identical to that seen in the published studies. We also saw a consistent relationship between difference-in-difference estimates of function and incremental QALYs across studies.

DISCUSSION

We present the results of a Markov model that estimates the effectiveness and cost-effectiveness of adding 17 nonpharmacologic interventions for CLBP to usual care. This model provides information beyond what is available from the individual studies, systematic reviews, and meta-analyses. The model estimates comparable results across studies by balancing baseline patient mixes (as would be expected with randomization), and using similar outcome measures (e.g., QALYs based on SF-6D, productivity costs, and healthcare costs). Also, because we had patient-level data and were able to categorize patients into chronic pain impact levels to better track outcomes, and we were able to examine the effectiveness and cost-effectiveness of interventions assuming all patients start with one level of chronic pain. These results are useful to the better design and targeting of nonpharmacologic interventions for CLBP, and the use of a common set of US-based cost inputs provides US policy makers with initial estimates of economic impacts.

Our model's health states were defined by chronic pain impact levels, and the results targeting high-impact chronic pain indicate that the biggest effects and costs for most interventions occur in these activity-limited patients. Given the number of other studies showing worse outcomes for patients with high-impact chronic pain—for example,

TABLE 2. One-Year Model Results for Each Nonpharmacologic Therapy Compared to Usual Care from the Societal and Payer Perspectives and Assuming a "Typical"* Mix of Chronic Low Back Pain Patients at Baseline

	Treatment Costs	Other Healthcare Costs (Societal)	Productivity Costs	Total Costs (Societal)	Total Costs (Payer)†	QALYs
Active trunk exercise (1)	$1077	−$898	−$419	−$241 (−1060, 934)	$188 (−433, 993)	0.033 (0.00, 0.06)
Active trunk exercise (2)	$1073	−$536	−$364	$173 (460, 1042)	$530 (103, 1073)	0.024 (0.00, 0.04)
CBT educational program	$77	−$286	−$101	−$310 (−1040, 517)	−$197 (−692, 341)	0.010 (−0.01, 0.03)
Chiropractic care	$199	−$252	−$88	−$142 (−1655, 1362)	−$40 (−1012, 935)	0.008 (−0.03, 0.04)
Exercise	$141	−$284	−$211	−$354 (−696, 46)	−$146 (−369, 96)	0.013 (0.00, 0.02)
Exercise + manipulation	$509	−$410	−$235	−$136 (−459, 257)	$117 (−84, 376)	0.016 (0.01, 0.03)
Flexion distraction (1)	$504	−$906	−$416	−$818 (−1557, 292)	−$389 (−929, 289)	0.033 (0.01, 0.05)
Flexion distraction (2)	$501	−$544	−$360	−$403 (−941, 230)	−$47 (−415, 358)	0.024 (0.01, 0.04)
Individualized acupuncture	$480	−$717	−$355	−$592 (−1430, 367)	−$202 (−708, 496)	0.025 (0.00, 0.05)
Manipulation	$480	−$362	−$225	−$106 (−429, 282)	$120 (−100, 357)	0.015 (0.01, 0.02)
Multidisciplinary program	$260	−$449	−$181	−$369 (−1168, 563)	−$172 (−699, 450)	0.015 (−0.01, 0.04)
Physical therapy	$406	−$439	−$190	−$223 (−1777, 1658)	−$13 (−1108, 1130)	0.015 (−0.03, 0.05)
Relaxation massage	$459	−$592	−$359	−$491 (−1195, 431)	−$116 (−566, 529)	0.023 (0.00, 0.04)
Spinal manipulation (3)	$520	−$13	$6	$513 (91, 888)	$457 (190, 726)	0.004 (−0.01, 0.02)
Spinal manipulation (4)	$520	−$472	−$85	−$37 (−774, 689)	$47 (−382, 514)	0.016 (0.00, 0.03)
Standardized acupuncture	$487	−$637	−$252	−$402 (−1208, 447)	−$117 (−614, 481)	0.021 (0.00, 0.04)
Structural massage	$448	−$406	−$286	−$244 (−978, 722)	$54 (−447, 658)	0.017 (−0.01, 0.04)
TCM acupuncture	$459	−$139	−$19	$302 (−304, 875)	$328 (−83, 691)	0.004 (−0.01, 0.02)
Therapeutic massage	$437	−$376	−$258	−$197 (−649, 296)	$69 (−202, 393)	0.015 (0.00, 0.03)
Yoga	$385	−$1626	−$531	−$1773 (−2730, −372)	−$1136 (−1784, −151)	0.048 (0.02, 0.07)

Each intervention is compared to the usual care arm of their study with the exception of the two studies (three interventions) that did not include usual care arms. For these we assigned two of the other US-based usual care arms based on the closest matches in terms of data collection schedules. The usual care arms assigned for each are (1) usual care (Sherman); (2) usual care (Moore); (3) self-care education (Cherkin, 2001); (4) usual care (Cherkin, 2009).

*Typical mix of patients with chronic low back pain was assumed to be 25% low-impact chronic pain, 35% moderate-impact chronic pain, and 40% high-impact chronic pain. The proportions roughly correspond to the average baseline proportions seen in the studies included in the model.

†The payer perspective used an estimate of other healthcare costs that excluded patient out-of-pocket payments and assumed that the payer covered all treatment costs. Note that the assumption of full coverage for treatment costs is in contrast with current payer policies (see Heyward et al, JAMA Network Open. 2018;1:e183044-e). Thus, these payer perspective costs are likely overstated.

CBT indicates cognitive behavioral therapy; QALY, quality-adjusted life-year; TCM, traditional Chinese medicine.

significantly higher healthcare costs, lower quality of life, worse mood, and more absenteeism[18–27]—it is not surprising that these patients would have a different response to treatment. However, this is the first study that examines how their response varies.

As with any Markov model, transition probabilities drive outcomes. Our transition probabilities were calculated from individual trial participants' transitions through the health states they experienced over the trial year. Healthcare costs are related to patients' health states, but health outcomes directly determine health states. Therefore, more confidence should be placed in the model's estimates of QALY gains than of costs. One US cost-effectiveness analysis alongside a randomized trial of mindfulness-based stress reduction (MBSR) and group CBT for CLBP did find QALY gains in the range shown in model results.[31] It also found that

MBSR was cost saving from the societal and payer perspectives, and that CBT was cost neutral from the societal and likely cost-effective ($24,000/QALY) from the payer perspective; therefore, our cost estimates are reasonable. Nevertheless, modeling cost results should be interpreted with caution, considered more for their relative than absolute values, and replicated in relevant settings.

Another recent Markov model used three health states (chronic pain, improved pain, and death) to examine the relative effectiveness and cost-effectiveness of cognitive and mind-body therapies for CLBP.[67,68] That model used 6-month cycles over 5 years, defined improved pain as ≥30% improvement in the Roland Morris Disability Questionnaire, and used other estimates for QALYs and healthcare costs as inputs. They concluded that yoga and MBSR offered high value for the money given their effectiveness

TABLE 3. One-Year Model Results for Each Nonpharmacologic Therapy Compared to Usual Care From the Societal and Payer Perspectives and Assuming That All Chronic Low Back Pain Patients Have High-Impact Chronic Pain at Baseline						
	Treatment Costs	Other Health-care Costs (Societal)	Productivity Costs	Total Costs (Societal)	Total Costs (Payer)*	QALYs
Active trunk exercise (1)	$1077	−$1824	−$915	−$1662 (−2977, 1293)	−$707 (−1499, 1106)	0.067 (−0.00, 0.11)
Active trunk exercise (2)	$1073	−$655	−$457	−$39 (−1241, 1719)	$413 (−339, 1446)	0.029 (−0.01, 0.06)
CBT educational program	$77	−$257	−$89	−$269 (−1731, 1434)	−$167 (−1046, 488)	0.008 (−0.04, 0.05)
Chiropractic care	$199	−$537	−$263	−$601 (−3275, 2420)	−$318 (−1510, 1411)	0.019 (−0.06, 0.09)
Exercise	$141	−$170	−$208	−$238 (−928, 505)	−$40 (−707, −5)	0.010 (−0.01, 0.03)
Exercise + manipulation	$520	−$472	−$354	−$307 (−884, 419)	$54 (−456, 281)	0.020 (0.00, 0.04)
Flexion distraction (1)	$504	−$1939	−$980	−$2415 (−3425, 341)	−$1386 (−2063, 389)	0.072 (0.00, 0.10)
Flexion distraction (2)	$501	−$770	−$522	−$791 (−1822, 359)	−$266 (−901, 466)	0.033 (0.01, 0.06)
Individualized acupuncture	$480	−$1100	−$651	−$1271 (−2646, 439)	−$577 (−1400, 380)	0.042 (0.00, 0.08)
Manipulation	$480	−$395	−$339	−$255 (−878, 430)	$83 (−492, 231)	0.019 (0.00, 0.04)
Multidisciplinary program	$260	−$360	−$145	−$245 (−1760, 1237)	−$86 (−1193, 653)	0.012 (−0.02, 0.05)
Physical therapy	$406	−$979	−$466	−$1039 (−4351, 2588)	−$525 (−1849, 1607)	0.033 (−0.06, 0.18)
Relaxation massage	$459	−$722	−$480	−$744 (−1938, 1108)	−$250 (−1218, 426)	0.030 (−0.01, 0.06)
Spinal manipulation (3)	$520	−$451	−$238	−$168 (−1174, 702)	$38 (−505, 634)	0.021 (−0.00, 0.05)
Spinal manipulation (4)	$520	−$1172	−$547	−$1199 (−2269, 86)	−$630 (−966, 603)	0.044 (0.01, 0.07)
Standardized acupuncture	$487	−$952	−$450	−$915 (−2426, 873)	−$419 (−1121, 611)	0.033 (−0.01, 0.07)
Structural massage	$448	−$534	−$422	−$508 (−1764, 1166)	−$76 (−1116, 702)	0.024 (−0.02, 0.06)
TCM acupuncture	$459	$63	$65	$587 (−924, 1823)	$517 (−268, 888)	−0.002 (−0.03, 0.03)
Therapeutic massage	$437	−$756	−$468	−$787 (−1734, 296)	−$293 (−193, 381)	0.029 (0.00, 0.06)
Yoga	$385	−$2717	−$1086	−$3419 (−4930, −71)	−$2174 (−2370, −145)	0.087 (0.01, 0.13)

Each intervention is compared to the usual care arm of their study with the exception of the two studies (three interventions) that did not include usual care arms. For these we assigned two of the other US-based usual care arms based on the closest matches in terms of data collection schedules. The usual care arms assigned for each are (1) usual care (Sherman); (2) usual care (Moore); (3) self-care education (Cherkin, 2001); (4) usual care (Cherkin, 2009).

The payer perspective used an estimate of other healthcare costs that excluded patient out-of-pocket payments and assumed that the payer covered all treatment costs. Note that the assumption of full coverage for treatment costs is in contrast with current payer policies (see Heyward et al, JAMA Network Open. 2018;1:e183044). Thus, these payer perspective costs are likely overstated.

CBT indicates cognitive behavioral therapy; QALY, quality-adjusted life-year; TCM, traditional Chinese medicine.

and cost-effectiveness, acupuncture, and CBT for pain offered intermediate value, and all four had evidence adequate to support coverage.

Although we believe this model is useful, it is not without limitations. It now includes the results for 10 large randomized trials and 17 nonpharmacologic interventions for CLBP. Many other studies have been done that could be added to increase the information available, and the added studies might include therapies that are not as effective. This model in its present state should be considered a demonstration of how the results of different studies can be compared, and its results should not be used to make decisions. With more examples of each intervention, we could also examine the effect of any differences in protocols across studies. It is possible to use calibration to estimate transition probabilities from published studies when patient-level data are not available. However, confidence in these calibrated results would be lower. We used one measure of chronic pain impact levels to define our health states. There could be other health state definitions or other measures of chronic pain impact that would be more appropriate and better track effects and costs. To obtain estimates of the incremental effects for three interventions, we assigned usual care arms from those available from the other studies. We do not know how close the assigned usual care arms are to the actual usual care underlying those studies, but the range in outcomes generated across the options assigned demonstrates the importance of including a usual care arm if a trial's results are to be generalizable.

Markov modeling of nonpharmacologic interventions for CLBP is feasible and provides useful information about the effectiveness and cost-effectiveness of these interventions relative to usual care. According to model assumptions these interventions all improve health-related quality of life (QALYs) over usual care, and most, significantly so. In addition, most of these interventions appear cost-effective (and even cost saving) from the payer and societal perspectives, and many of the interventions have their largest impacts on those with high-impact chronic pain. Modeling leverages the investment made in existing trials to provide more useful information than is available from the published studies. We recommend this modeling effort be expanded to include data from all existing studies of nonpharmacologic interventions for chronic low back pain.
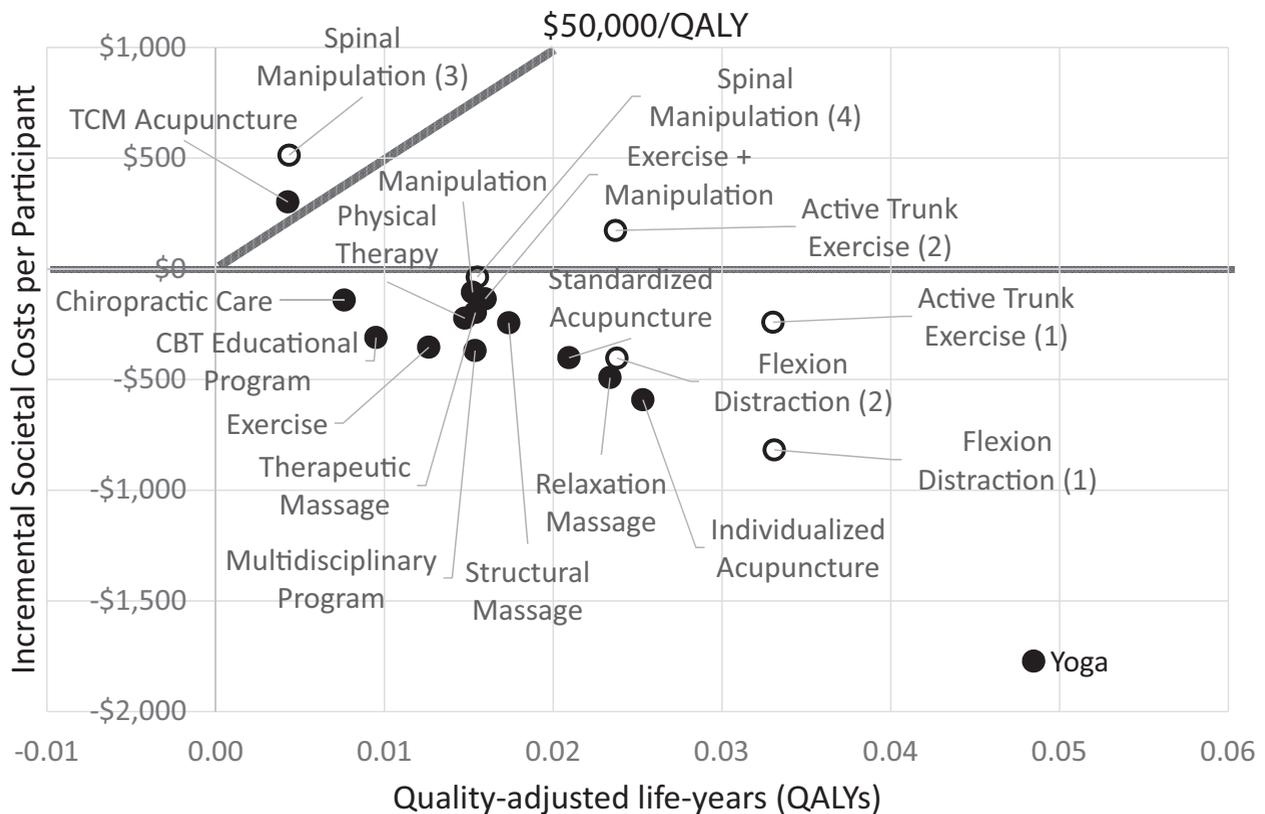
Figure 2. Effectiveness and cost-effectiveness from the societal perspective for 17 nonpharmacologic interventions compared to usual care alone for a typical* chronic low back pain patient population. Each intervention represented by a solid circle is compared to the usual care arm of its study. The three interventions identified with open circles came from two studies that did not include usual care arms. For these we assigned two US-based usual care arms from other studies. The usual care arms assigned for each are (1) usual care (Sherman); (2) usual care (Moore); (3) self-care education (Cherkin, 2001); (4) usual care (Cherkin, 2009). Societal costs consist of three types of costs: the cost of the intervention itself, all other direct healthcare costs, and the indirect cost of productivity loss through absenteeism to employers. Incremental societal costs are these costs for each therapy minus the costs of usual care. *A typical chronic low back pain patient population was assumed to have 25% of patients with low-impact chronic pain, 35% with moderate-impact chronic pain, and 40% with high-impact chronic pain. These proportions roughly correspond to the average proportions seen in the studies included in the model. QALY indicates quality-adjusted life-years.

> ➤ **Key Points**

❑ Decision analytic (*e.g.*, Markov) modeling can be used to synthesize evidence and compare the effectiveness and cost-effectiveness of the many nonpharmacologic therapies recommended for chronic low back pain.

❑ Some therapies appear to be more effective than others for those with high-impact chronic low back pain (active trunk exercise, chiropractic care, exercise combined with manipulation, flexion-distraction, individualized and standardized acupuncture, physical therapy, spinal manipulation, yoga, and relaxation, structural and therapeutic massage), and these therapies achieve their largest benefits in this population.

❑ This information highlights the need to identify chronic low back pain subpopulations to better target appropriate interventions.

❑ According to the assumptions used in this model, many of the nonpharmacologic interventions recommended for chronic low back pain are more effective and cost-effective compared to usual care, and a number may also be cost saving.

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