Modern acupuncture-like stimulation methods: a literature review

Min-Ho Jun, Young-Min Kim, Jaeuk U. Kim

KM Fundamental Research Division, Korea Institute of Oriental Medicine, Daejeon, Korea

Abstract

Acupuncture therapy has been proved to be effective for diverse diseases, symptoms, and conditions in numerous clinical trials. The growing popularity of acupuncture therapy has triggered the development of modern acupuncture-like stimulation devices (ASDs), which are equivalent or superior to manual acupuncture with respect to safety, decreased risk of infection, and facilitation of clinical trials. Here, we aim to summarize the research on modern ASDs, with a focus on featured devices undergoing active research and their effectiveness and target symptoms, along with annual publication rates. We searched the popular electronic databases Medline, PubMed, the Cochrane Library, and Web of Science, and analyzed English-language studies on humans. Thereby, a total of 728 studies were identified, of which 195 studies met our inclusion criteria. Electrical stimulators were found to be the earliest and most widely studied devices (133 articles), followed by laser (44 articles), magnetic (16 articles), and ultrasound (2 articles) stimulators. A total of 114 studies used randomized controlled trials, and 109 studies reported therapeutic benefits. The majority of the studies (32%) focused on analgesia and pain-relief effects, followed by effects on brain activity (16%). All types of the reviewed ASDs were associated with increasing annual publication trends; specifically, the annual growth in publications regarding noninvasive stimulation methods was more rapid than that regarding invasive methods. Based on this observation, we anticipate that the noninvasive or minimally invasive ASDs will become more popular in acupuncture therapy.

1. Introduction

Stimulation of acupoints and meridians has been an important therapeutic modality in traditional Eastern medicine, and it has also become popular in the West, as its clinical effectiveness has been demonstrated through extensive research. Acupuncture and related modern technologies are increasing in popularity worldwide. According to a 2002 World Health Organization report, acupuncture treatment was shown to be effective in controlled trials of 29 diseases, symptoms, or conditions. However, the safety of acupuncture has engendered controversy with respect to infection, inflammation, and pain management.
Clinical effectiveness of acupuncture has widely been studied during the past four decades. In addition to the demonstrated effectiveness of traditional acupuncture practices, increased demand has arisen for the development of modern acupuncture-like stimulation devices (ASDs), which are simpler to quantify and standardize and are less dependent on the manipulation techniques of individual clinicians. The first modern ASD dates back to the early 1950s, which was based on electrical stimulation (ES). In addition to its long history, ES is the most extensively studied ASD. Recently, however, several types of ASDs have extensively been studied for their clinical effectiveness and noninferiority to manual acupuncture, including laser stimulation (LS) and magnetic stimulation (MS). In this review, we summarize recent studies of popular ASDs. We first describe the most popular types of ASDs, discuss their clinical effectiveness and target symptoms, and finally, discuss the annual research trends regarding popular ASDs.

2. Methods

To analyze the popularity and features of methods for stimulation of acupoints, we searched for studies in the Medline, PubMed, Cochrane Library, and Web of Science electronic databases from their inception to June 2014. First, we searched for studies related to acupuncture or acupoint stimulation, which yielded >22,000 studies, of which approximately 20,000 were redundant. Among the latter studies, approximately 3000 were related to moxibustion, 1600 to massage (or acupressure), 200 to the cupping method, 5400 to ES, 900 to LS, 700 to MS, and 300 to ultrasound stimulation (US). To narrow the search scope to ASDs, we refined the search to [(acupoint* or “acupuncture point*” or meridian*) and (stimul* or irritat* or excit* or response or respon* or react* or reflex or measur* or diagnos*) and (electric* electro* or magnet* or infrared or IR or laser or ultraviolet or UV or ultraso*) not (rat or monkey or dog or pig or cat or mouse or mice or rabbit or rodent*)]. We excluded laboratory experiments on animals, studies that were not written in English, and reviews. We searched 728 articles obtained from the electronic databases, excluding 489 articles that included studies on animals, manual acupuncture-only clinical trials, non-English-language articles, and review articles by screening the titles and abstracts. A total of 44 studies were excluded from the selected 239 articles because of duplication. Finally, 195 studies met the inclusion criteria and were evaluated in detail. The topics of these 195 articles were ES (133), LS (44), MS (16), and US (2), as shown in Fig. 1. Prior to describing the results of the detailed analysis, we introduce the features and research history of ES, LS, MS, and US in the following sections.

2.1. Electrical stimulation

Low electrical impedance and high conductance are recognized as typical electrical properties of acupoints and meridians. In the Western hemisphere, the electrical properties of acupoints and meridians have been investigated since the 1950s. In 1958, Niboyet and Mery reported the points with low skin impedance using the Wheatstone bridge, whereas in 1962, Kramar showed that acupoints have high capacitance compared with neighboring points. Voll devised an ES device to apply to acupoints and meridians, thereby establishing a method that was called “electroacupuncture according to Voll.” This method of Voll greatly stimulated clinical and research activities associated with ES at acupoints and meridians. In the East in 1956, Nakatani reported that electrical pathways connected the points with low skin resistance and named them “Ryodoraku.” Today, ES can be classified into five types: electroacupuncture (EA), transcutaneous electrical acupoint stimulation (TEAS), auricular electroacupuncture (AEA), transcutaneous electrical nerve stimulation (TENS), and electrical heat acupuncture (EHA). EA is an electrical, minimally invasive stimulation technique applied to acupoints. TEAS is an electrical, noninvasive stimulation technique applied to acupoints. AEA is a subtype of EA applied to acupoints of the ear. TENS is an electrical, noninvasive stimulation technique applied to the nervous system (nonacupoints). EHA is similar to EA with the exception that a needle heated by an electric current is used at acupoints. Of the 133 articles on ES, 54 pertained to EA, 69 to TEAS, six to AEA, three to TENS, and one to EHA. To simplify the discussion, we categorized ES into EAs and TEASs, where EAs represented
all invasive techniques, such as EA, AEA, and EHA, and TEASs included all noninvasive techniques, such as TEAS, auricular TEAS, and TENS.

2.2. Laser stimulation

Studied since the 1970s, LS is used to expose acupoints of the human body to low-energy laser beams. A review article noted that studies using LS were conducted between 1970 and 1972 in the USSR. Nevertheless, Friedrich Plog’s study published in 1976 is well known as the first report of implementation of LS at acupoints. Since the 1980s, LS has been recognized as an effective method for stimulating acupoints without needles. Applications of LS at acupoints were mostly described as noninvasive in the studies reviewed, with only a few being described as invasive. Here, we do not distinguish invasive techniques from noninvasive stimulation.

2.3. Magnetic and ultrasonic stimulation

MS is used to access the body’s magnetic fields by stimulating acupoints, and MS of acupoints has been studied since the 1970s. Transcranial magnetic stimulation is one of the most frequently used MSs and was introduced by Barker in 1985. In 1980, Inoue applied for a patent for a device used for MS of body acupoints, and in 1982, Katayama reported the meridian magnetic analgesia of acupuncture stimulation (published in Japanese). The MS used in all 16 papers consisted of noninvasive stimulations at acupoints. US is used to irritate acupoints using a narrow, cylindrical, high-frequency beam of sound. Characteristics of phonation and sound transmission in meridians were reported in the 1980s, and a study on US of acupoints was published by Jin in 1984. Only two studies that we identified in the electronic databases were relevant.

3. Results

The aforementioned four types of ASDs were classified into the following 13 categories according to the stimulation purposes: (a) analgesic effect; (b) pain relief; (c) physiological change; (d) improvement of the alimentary system; (e) prevention of nausea and vomiting; (f) recovery of muscle fatigue or improvement of muscle strength; (g) reduction of body weight; (h) treatment of depression; (i) treatment of addiction, such as addiction to tobacco, narcotics, and alcohol; (j) treatment of stroke; (k) treatment of various diseases; (l) characteristics of stimulation; and (m) brain activity. Fig. 2 shows how the four types of ASDs were distributed between the 13 categories for research purposes. It also shows the ratio of randomized controlled trials (RCTs) to efficacies for the 13 categories. The

Fig. 2 – Distribution of the four ASDs with respect to the 13 research categories from (a) to (m) whereby the numbers of RCTs and the therapeutic effectiveness are shown for each category. Numbers reflect the article counts, with the numbers in parentheses for the four types indicating the number of cases of overlap between the stimulations, and the numbers in parentheses below the efficacy (%) are presented when the efficacy was unclear. In RCT (%) = A/(A + B) % and (O:X = A:B), A is the number of RCTs and B is the number of non-RCTs. The same formula was applied to the efficacy percentages. When the efficacy was unclear, indicated by the numbers in parentheses, we considered those studies as not effective in computing the percent values. For example, % value = A/(A + B + b) for efficacy [O:X = A:B(b)].

ASD, acupuncture-like stimulation device; ES, electrical stimulation; LS, laser stimulation; MS, magnetic stimulation; RCT, randomized controlled trial; US, ultrasound stimulation. O = yes, X = no. Example: RCT (O:X) = (RCT:non-RCT), Efficacy (O:X) = (efficacious:not efficacious).
| Reference       | Stimulation type | Stimulation site | Symptom Control | Control                                                                 | Effect                                                                                   |
|-----------------|------------------|------------------|-----------------|--------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| Jiang et al     | TEAS             | LI4, PC8, L4, PC6, ST36 | Healthy         | 46 individuals, TEAS/mock TEAS                                          | Analgesic effect                                                                          |
| Wang et al      | TEAS             | LI4, PC6, ST36    | Healthy Sinusotomy | 60 patients, random TEAS/control: no stimulation                          | Analgesic effect                                                                          |
| Zhang et al     | TEAS             | T3 acupoints     | Ambulatory surgery Hemorrhoids | 72 women, random TEAS/sham                                                  | Recovery & decrease of anesthesia                                                                 |
| Wu et al        | EA               | GV1, BL57        | Total hip arthroplasty surgery | 120 cases, random EA (40)/sham EA (40)/blank (40)                              | Effects of preemptive analgesia                                                                 |
| Lan et al       | TEAS             | Bi PC6, LI14, ipsilateral to surgery sire ST36, GB31 | Healthy | 68 elderly patients, random TEAS/sham TEAS                                  | Reduction of postoperative analgesic requirement                                              |
| Zheng et al     | EA               | GV24, EX-HN3     | Orotacheally intubated patients Healthy | 45 patients, random, no treatment/sham EA/EA                                  | Sedation & analgesia                                                                        |
| Cheing and & Chan | TEAS/TENS         | Right elbow LI11, Nonacupoint (right superficial radial nerve) | Healthy | Randomized controlled trial, 45 individuals, random TEAS (15)/TENS (15)/control-no stim (15) | Hypoalgesic effects (acupuncture points & nerve points)                                      |
| DeSantana et al | TENS             | Around the incision | Unilateral inguinal herniorrhaphy with epidural anesthetic technique | Prospective, randomized, double-blinded, placebo-controlled study, 40 patients, TENS (20)/placebo-TENS (20) | Hypoalgesic effect for postoperative pain                                                    |
| Barlas et al    | EA               | Bi LI10, HT5/ipsilateral GB34, ST38 | Healthy (acupuncture naïve) | Randomized, double-blinded, placebo-controlled study, 48 volunteers, control/placebo-EA no stim/high-intensity EA/low-intensity EA | Hypoalgesic response                                                                        |
| Leung et al     | EA               | Left SP1, LR1    | Healthy          | 13 individuals, EA/before-EA/-after-EA (time sequence)                     | Analgesic benefit                                                                          |
| Litscher       | Acupressure/MA/LS | EX-HN3           | Healthy          | Randomized, controlled, blinded crossover trial, 20 volunteers, acupress/MA/LA; APs/non-APs | ECG similarities of acupressure-induced sedation & general anesthesia (all)                  |
| Zhang et al     | EA               | Acupoints        | Healthy          | Eight8 individuals, EA/mock-EA                                            | Analgesic effect                                                                            |
| Attele et al    | TEAS             | LI4, PC6         | Healthy          | 22 individuals, TEAS/control                                               | Analgesic effect                                                                            |
| Chesterton et al | TENS/TEAS       | GB34, radial nerve or extrasegmental | Healthy         | Randomized, double-blind, sham-controlled study, 240 participants, six6 TENS (180; 90 m, 90 f)/control (30; 15 m, 15 f)/sham TENS (30; 15 m, 15 f); 4/110 Hz, intensity, site | Hypoalgesic effect                                                                          |
| Yuan et al      | TEAS             | LI4, PC6         | Healthy          | 20 individuals TEAS/morphine/TEAS + morphine/control                       | Analgesia effect                                                                            |
| Morioka et al   | EA               | ST36, GB34, BL60 | Healthy          | 14 volunteers, EA/control                                                  | No difference in minimum alveolar anesthetic concentration                                 |
| Lin et al       | EA               | Bi ST36          | Lower abdominal surgery | Randomly, 100 women, control (25/sham-EA no stim (25)/LF-EA 2 Hz (25)/HF-EA 100 Hz (25) | Reduction of postoperative analgesic requirements & side effects (LF-EA, HF-EA)               |
| Greif et al     | ATEAS            | Auricular acupoints | Healthy         | Randomized, double-blind, crossover trial, 20 volunteers (10 m, 10 f), ATEAS/no treatment | Reduction of anesthetic requirement                                                          |
| Chen et al      | TEAS/TENS        | ST36/dermatomal level | Total abdominal hysterectomy or myomectomy procedures | Randomized controlled trial, 100 women, sham-TEAS no stim (25)/non-APs TEAS (25)/dermatomal-TENS (25)/TEAS (25) | TENS was as effective as TEAS, both were more effective than stim at non-APs                  |
numbers shown in the uppermost boxes in Fig. 2 signify the numbers of articles. The numbers of overlapping articles are shown in parentheses under the 13 categories of the four ASDs, and the numbers in parentheses below the efficacy (%) are presented when the efficacy was unclear.

To investigate the effectiveness of ASDs, we analyzed the efficacy of each stimulation type through the articles reporting effectiveness. The effectiveness of ES was stated in the fields of analgesic effect (94.7%), pain relief (90.9%), and reduction of nausea and vomiting (90.9%) based on the sample size of > 1000 trials. Based on the sample size of > 100 trials, ES was shown to be effective in improving the alimentary system (100%), improving muscle strength (100%), reducing body weight (100%), treating various addictions (60%), and treating stroke (100%), whereas LS was effective for pain relief (62.5%) and treating various addictions (100%). Based on a sample size of < 100 trials, ES was shown to be a therapeutic possibility in various diseases such as orthostatic intolerance, autism spectrum disorders, supratentorial craniotomy, tinnitus, asthma, dyspnea, distress, and anxiety. LS presented potential in the treatment of nausea and vomiting, depression, menopausal symptoms, cholecystitis, renal failure, head injury, and interstitial cystitis. MS was a possible treatment for muscle and treating various addictions (100%). Based on the sample size of > 1000 trials, ES was shown to be superior to that of TEASs in one study. Of 1046 individuals who received TEASs, 926 experienced relief or a reduction in various types of pain. Of the 877 individuals who received TEASs, 728 also experienced pain relief. Of the 435 individuals who received LS, 230 experienced relief of dysmenorrhea pain or carpal tunnel syndrome pain, whereas 50 individuals who received US experienced an effect on short-term segmental antinociception. Six of the 42 papers reported no statistically significant effect on pain relief when TEASs, LS, and LS combined with paracetamol and chlorpromazine, and LS were applied to the acupoints of study participants.

### 3.2. Pain relief

As shown in Table 2, presenting the studies reporting the effect on pain relief, 15 articles reported using TEASs, four other acupoint stimulations such as US were used in one study, and LS was used in eight studies. TEASs and EAs were compared in a total of 872 individuals to evaluate their effect on pain relief. Both had an effect on pain relief in two studies; however, the effect of EAs was reported to be superior to that of TEASs in one study. Of 1046 individuals who received TEASs, 926 experienced relief or a reduction in various types of pain. Of the 877 individuals who received TEASs, 728 also experienced pain relief. Of the 435 individuals who received LS, 230 experienced relief of dysmenorrhea pain or carpal tunnel syndrome pain, whereas 50 individuals who received US experienced an effect on short-term segmental antinociception. Six of the 42 papers reported no statistically significant effect on pain relief when TEASs, LS, and LS combined with paracetamol and chlorpromazine, and LS were applied to the acupoints of study participants.

### 3.3. Treatments of the alimentary system

As summarized in Table 3, ES (TEASs and EAs) was the primary ASD method for treating digestive disorders. Of these studies, seven that investigated TEASs and three that evaluated EA93–95 comprise this category. In total, 149 individuals who received TEASs experienced a beneficial effect on the alimentary system, as did 68 individuals who received EA. No study reported statistically insignificant results regarding stimulation of the alimentary system.

### 3.4. Prevention of nausea and vomiting

All the studies shown in Table 4 employed ASDs for the prevention of nausea and vomiting. ES was primarily applied for the prevention or treatment of nausea and vomiting, except for one study that used LS for this purpose. TEAS was the main method used for preventing nausea and vomiting; we retrieved nine articles on TEASs, two on EA, and one on LS. A total of 830 individuals who received TEASs experienced an effect on prevention, reduction, or treatment of postoperative nausea and vomiting or nausea or vomiting. A total of 224 individuals who received EA also

| Reference | Stimulation type | Stimulation site | Symptom | Control | Effect |
|-----------|-----------------|-----------------|---------|---------|--------|
| Wang et al14 | TEAS | LI4 | Healthy women undergoing lower abdominal procedures | Random, 101 participants, PCA (26)/PCA + LP-TEAS (25)/PCA + HP-TEAS (25)/PCA + sham-TEAS no stim (25) | Decrease in PCA opioid requirement & opioid-related side effects (HP-TEAS) Analgesic effect of MA on painful heat stim, no effect on pain (LA) |
| Brokhaus and Elger &43 | LS/MA | Bi LI4, EX-UE | Healthy | Double-blind, 40 probatoiners, MA-LI4/LS-LI4, EX | Analgesic effect of MA on painful heat stim, no effect on pain (LA) |

AP: acupuncture point; ASD, acupuncture-like stimulation device; ATEAS, auricular TEAS; EA, electroacupuncture; ECG, electrocardiogram; HF, high frequency; HP-TEAS, high power TEAS; LA, laser acupuncture; LF, low frequency; LP-TEAS, low power TEAS; LS, laser stimulation; MA, Manual acupuncture; PCA, patient-controlled analgesia; stim, stimulation; TEAS, transcutaneous electrical acupoint stimulation; TENS, transcutaneous electrical nerve stimulation.
| Reference      | Stimulation type | Stimulation site | Symptom Control Effect | Reference Stimulation type | Stimulation site | Symptom Control Effect |
|----------------|------------------|------------------|------------------------|-----------------------------|------------------|------------------------|
| Mucuk & Baser 44 | TEAS             | LI4, SP6         | Pregnant women         | Random TEAS/no TEAS         | Labor pain relief |
| Sun et al45     | TEAS             | PC6              | Driver fatigue         |                             |                  |
| Vassal et al46  | TENS             | Left common peroneal nerve | 20 individuals, TENS/sham TENS (left thigh) | Pain relief |
| Kim et al48     | EA               | Bi LI4, TE3, GV39, GV41, SP6, LR3, Ba Feng, Ba Xie Bi ST36, GB39, SP9, PC6, LR3, GB41 | CIPP Randomized, patient-observer-blinded, controlled trial, 40 patients, EA (20)/sham EA (20) | Treatment for CIPP trials |
| Lee et al60     | EA               | Bi ST36, GB39, SP9, PC6, LR3, GB41 | PDN 5-armed, randomized, controlled pilot trial, EA (15)/sham EA (15)/usual care (15) | Treatment for PDN trials |
| Mucuk et al47   | TEAS             | Bilateral LI4    | Labor pain             | Random TEAS/control no TEAS, all standard treatments | Pain relief, not statistically significant |
| Ni et al48      | TEAS             | Bilateral PC6    | Children with congenital heart defects | 70 eligible children, random, TEAS (34)/control-no stim (36) | Attenuation of myocardial injury in children undergoing cardiac surgery |
| Wu et al49      | TEAS             | LI4, SP6         | Gyneocology patients (primary dysmenorrhea) | Randomized controlled trial, 66 patients (6), TEAS (36)/control-no stim (36) | Mitigation of pain in dysmenorrhea |
| Yoshimizu et al72 | EA/TEAS        | For acupoints in trapezius muscle | Shoulder & neck pain | Randomized crossover trial, 90 patients, EA/TENS | Reduction in pain (EA > TEAS) |
| Musial et al73  | EA               | LI4, LI10        | Healthy                | Double-blind design, 125 individuals, EA (25)/tramadol (25)/ibuprofen (25)/placebo pill (25)/no treatment (25) | Reduction of experimentally induced ischemic pain |
| Choi et al61    | EA/meditation    | LI4, LI10        | Vipassana meditators   | Semirandomized trial, meditators (8)/nonmeditators (20)-EA/nonmeditators (20)-no EA | Reduction in the pain induced by SETT |
| Yeh et al50     | TEAS             | BL40, GB34, HT7, PC6 | Spinal surgery receiving patients | Placebo- & sham-controlled study, random TEAS (30)/TEAS-sham point (30)/no TEAS (30) | Reduction in postoperative pain, analgesic usage |
| Montenegro et al71 | TEAS              | TE5, CV6         | Healthy                | 32 volunteers, random TEAS/sham TEAS | Increase in the latency of pain threshold |
| Yeh et al72     | TEAS             | Acupoints        | Lumbar spinal surgery  | Randomized controlled repeated measures design, 99 patients, ES/sham-AP ES/no ES | Improvement of acute postoperative pain management without adversely affecting vital signs |
| Takamjani et al74 | LS               | Acupoints        | Wrist pain             | Randomized controlled trial, 70 women, LS (33)/control (37) no LS | Increase in mean value of pain threshold |
| Lee & Lee42     | EA               | Bi BL32, BL33, GB30 | Chronic prostatitis/chronic pelvic pain syndrome | Randomized controlled double blind pilot trial, 48 women, LA (18)/placebo-LA (30) | Dysmenorrhea treatment |
| Kempf et al48   | LS               | Bi SP6, LR3, LI4, right CV3, ST36 | Minimum menstrual pain | Randomized controlled double blind pilot trial, 48 women, LA (18)/placebo-LA (30) | Pain relief effect |
| Glazov et al52  | LS               | Acupoints        | Chronic nonspecific low-back pain | Double blind, 2-group parallel randomized trial, 100 participants, LA/sham-LA | Not showing a specific effect for chronic low-back pain |
| Reference         | Stimulation type | Stimulation site                                      | Symptom                           | Control                                                                 | Effect                                                                 |
|-------------------|------------------|-------------------------------------------------------|-----------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|
| Chan et al        | EA               | Acupoints on the wrist                                | Chronic neck pain                 | Single-blind, randomized, sham-controlled trial, 49 patients, EA (23)/sham-EA (27) | Significant improvements of chronic neck pain                         |
| Jubb et al        | EA               | Acupoints                                             | Osteoarthritic knee pain & disability | Blinded randomized trial, MA (34)/EA (34)/sham MA (34)                  | Symptomatic improvement                                               |
| Srbely et al      | US               | Right supraspinatus trigger point L4, PC8; Jiaogan, Shenmen, Shen, Waifei, Naogan, Pizhixia (ear acupoints) | Identifiable myofascial trigger points | Randomized controlled study, 50 individuals, random US/sham US (off) Randomized controlled, 40 patients, PCA + TEAS (20)/PCA (20) | Short-term segmental antinociceptive effects on TPs Enhancement of the effect of pain relief & reduction of adverse reactions |
| Ye et al          | TEAS + PCA       | –                                                     | Craniotomy & required pain relief following surgery |                                                                 |                                                                 |
| Michalek-Sauberer et al | AEA        | Auricular shenmen, mouth, tooth                       | Molar tooth extraction            | Prospective, randomized, double-blind, placebo-controlled study, 149 patients, AEA (76)/AMA (37)/sham AEA no stim no needle (36) | No reduction in either pain intensity or analgesic consumption in a molar tooth extraction model |
| Zhang et al       | EA               | GB34, GB39                                            | Healthy (right handiness)         | 12 volunteers, EA/sham-points EA/shallow EA subcutaneous needling      | Pain relief                                                           |
| Yip et al         | TEAS + EMMW      | –                                                     | Subacute neck or low-back pain    | Randomly, 47 individuals, TEAS + EMMW (23)/control (24)                | Reduction in pain intensity, stress, & stiffness level Therapy for periarthritis of shoulder, no significant differences (TEAS/EA) |
| Fang et al        | TEAS/EA          | Acupoints                                             | Periarthritis of shoulder at different stages | 360 cases, TEAS (186)/EA (174)                                        | Therapy for periarthritis of shoulder, no significant differences (TEAS/EA) |
| Aigner et al      | LS + paracetamol, chlorozemalone AEA | 22 acupuncture points                                 | Whiplash injuries                 | Prospective, randomized placebo-controlled trial, LA (23)/placebo-LA (23) 94 women, random, AEA (32)/AMA (32)/pharm. (30) | Ineffective in management of whiplash injuries Reduction of pain intensity |
| Sator-Katzenschlager et al | AEA     | Auricular 29, 55, 57                                | In vitro fertilization            |                                                                 |                                                                 |
| Wong et al        | EA               | LI4, GB34, GB36, TE8                                  | Operable non-small cell lung carcinoma patients who received thoracotomy | Random, 25 patients, EA (13)/sham-EA (12)                               | Management of post-thoracotomy wound pain                             |
| Weng et al        | TEAS             | LI10, LI11                                            | Tennis elbow pain for at least 3 mo | Randomly, 20 patients, 5 kHz modulated LF-TEAS 2Hz (20)/5 kHz modulated HF-TEAS 100Hz (20)/sham-TEAS, different time slots | Effective in the treatment of tennis elbow pain (LF-TEAS, HF-TEAS)     |
| Tsui & Cheing     | EA/EHA           | 6 acupuncture points                                  | Chronic low-back pain             | 42 individuals, random EA/EHA/control; all exercise                    | Treatment of chronic low-back pain Treatment of chronic low-back pain |
| Sator-Katzenschlager et al | AEA | Auricular acupuncture points 29, 40, 55 | Chronic low-back pain Chronic low-back pain | Prospective, randomized, double-blind, controlled study, 61 patients, random AEA (31)/sham-AEA no stim (30) |                                                                 |
| Sator-Katzenschlager et al | AEA | Cervical spine, shenmen, cushion | Chronic cervical pain patients without radicular symptoms with insufficient pain relief | Prospective, randomized, double-blinded, controlled study, 21 patients, EA (10)/control (11) | Treatment of chronic cervical pain |
Table 2 (Continued)

| Reference          | Stimulation type | Stimulation site | Symptom Control Effect | Control | Effect |
|--------------------|------------------|------------------|------------------------|---------|--------|
| Ng et al<sup>70</sup> | EA/TEAS          | ST35/EX-LE4      | OA-induced knee pain   | Single-blinded randomized controlled trial, 24 individuals (1 m, 23 f), EA (8)/TEAS (8)/control standard therapy (8) | Reduction of OA-induced knee pain |
| Naeser et al<sup>80</sup> | LS/TENS          | Shallow acupuncture points/wrist | CTS                   | Randomized, double-blind, placebo-controlled, crossover trial, 11 cases, red LS/IR LS/TEAS/sham (off) | Treating CTS pain |
| Tsui & Leung<sup>71</sup> | EA               | GB34, ST38       | Chronic tennis elbow   | Single-blinded randomized controlled trial, 20 patients, MA/EA | Treating patients with tennis elbow |
| Zoghi & Jaberzadeh<sup>57</sup> | ATEAS/ATENS      | 4 auricular acupoints | Healthy               | Double-blind within-subject design, randomly, 90 individuals, HV-ES (30)/HV-sham-ES non-APs (30)/no ES (30) | Increase in experimental pain threshold (HV-ES, sham) |
| Lorenazana<sup>58</sup> | TEAS             | HT7, LI4         | Episiotomy pain       | Randomized, double-blind, controlled trial, 68 patients, TEAS (38)/control (30) | Relief of episiotomy pain (TEAS > lidocaine) |
| King et al<sup>103</sup> | ALS              | Auricular acupoints | Healthy               | 80 individuals, ALS (41)/control (39) sham-ALS | Increase in mean pain threshold after treatment |
| Waylonis et al<sup>104</sup> | LS               | Acupoints        | Myofascial pain syndromes (fibrositis, fibromyalgia) | Crossover double-blind trials, 62 patients, LS/placebo | No statistical difference between the treatment and placebo groups |
| Kreczi & Klingler<sup>85</sup> | LS               | Acupoints        | Radicular and pseudoradicular pain syndromes | Prospective randomized single-blind crossover study, 21 patients, LS/mock LS | Mean pain levels (lower) |
| Ernst & Lee<sup>106</sup> | EA               | LI4              | Normal individuals    | Crossover repeated-measure design, 5 individuals, control/EA/EA + naloxone/EA + placebo | Pain threshold increase |

AEA, auricular electroacupuncture; ALS, auricular laser stimulation; AMA, auricular manual acupuncture; AP, acupuncture point; ASD, acupuncture-like stimulation device; ATEAS, auricular TEAS; ATENS, auricular TENS; CIPN, chemotherapy-induced peripheral neuropathy; CTS, carpal tunnel syndrome; EA, electroacupuncture; EHA, electrical heat acupuncture; EMMW, electromagnetic millimeter wave; ES, electrical stimulation; f, female; m, male; HF, high frequency; HV, high voltage; IR, infrared; LA, laser acupuncture; LF, low frequency; LS, laser stimulation; MA, manual acupuncture; OA, osteoarthritis; PCA, patient-controlled analgesia; PDN, painful diabetic neuropathy; pharm, pharmacological treatment; SETT, submaximum effort tourniquet technique; stim, stimulation; TEAS, transcutaneous electrical acupoint stimulation; TENS, transcutaneous electrical nerve stimulation; TP, trigger point; US, ultrasound stimulation.

experienced either the same effect or controlled emesis, whereas 40 individuals who received LS experienced a decrease in the incidence of vomiting. We observed that TEAS has been steadily applied in the prevention of nausea and vomiting, and exceeded EA in the number of clinical studies since 2003. This finding implies that the effectiveness of TEAS in preventing nausea and vomiting has been confirmed, and that TEAS was preferred to EA because of the infection risk and pain due to the use of needles with EA.

3.5. Improvement of the muscle system

Studies regarding ASDs that were related to the recovery of muscle fatigue or improvement of muscle strength are shown in Table 5. MS and ES were used to reduce muscle fatigue or improve muscle strength. This category included two studies on MS<sup>108,109</sup> and five studies<sup>110–114</sup> on ES. The two MS studies, which were conducted by the same research group, reported the effective recovery of muscle fatigue. One study<sup>109</sup> reported better performance of MS than TEAS with respect to the therapeutic effect on muscle fatigue, and we expect more studies to validate this report.

3.6. Reduction in body weight

All the papers investigating the reduction in body weight were associated with ES, as shown in Table 6. EAs<sup>115,118,119</sup> and TEASs<sup>116,117</sup> were applied to facilitate the reduction in body weight. One study<sup>117</sup> stated that TEAS was as effective as EA in weight reduction. A total of 193 individuals who received ES experienced a reduction in body weight or fat, and an improvement in body mass index or body composition. All the studies reporting on the reduction in body weight claimed significant effects. More studies are required to substantiate the effectiveness of ES for body weight reduction.
Table 3 – Summary of studies on the effects of the four ASDs on alimentary system

| Reference         | Stimulation type | Stimulation site | Symptom                      | Control            | Effect                                           |
|-------------------|------------------|------------------|------------------------------|--------------------|--------------------------------------------------|
| McNearney et al16  | TEAS             | PC6, ST36        | SSc                          | 17 patients, all TEAS | Enhancement of gastric myoelectrical functioning in SSc |
| Leung et al87     | TEAS             | LI4, PC6, ST36   | Healthy                      | 40 individuals, random PEAS/placebo PEAS | Reduction of rectal discomfort                     |
| Chen et al99      | EA               | ST36, ST37, ST25, ST28, ST36 | Female constipation          | Single-blind, randomized trial, 30 females, EA (14)/sham EA (16) | Improvement of constipation                         |
| Liu et al18       | TEAS             | PC6, ST36        | Functional dyspepsia         | Double-blind, crossover study, 27 patients, random acute-TEAS/chronic (2w) TEAS | Improvement of dyspepsia symptoms                   |
| Wang et al94      | EA               | ST36, LI4        | Type 2 diabetes (symptoms of gastroparesis) | Single-blind, randomized pilot study, 19 patients, EA (9)/sham EA (10) | Reduction of the dyspeptic symptoms of diabetic gastroparesis |
| Sallam et al89    | TEAS             | Gastrointestinal (GI) acupoints ST36, PC6 | SSc                          | 17 patients, TEAS/baseline | Treatment of upper GI symptoms                    |
| Xu et al91        | EA               | ST36, PC6        | Functional dyspepsia         | 19 patients, acute-EA (10)/short-term (2w) EA (9) | Relief of dyspeptic symptoms                       |
| Zou et al92       | TEAS             | PC6              | Healthy                      | Random, 26 volunteers, TEAS/sham APs-TEAS/naloxone | Inhibition of frequency of transient lower esophageal sphincter relaxations |
| Xing et al90      | TEAS             | ST36, PC6        | Diarrhea-predominant IBS Healthy (males) | 7 patients, TEAS/sham-TEAS/control | Reduction of rectal sensitivity in IBS patients |
| Chang et al91     | TEAS             | ST36             | Healthy (males)              | 15 volunteers (males) EA/TEAS | Enhancement of gastric myoelectrical regularity, bradygastria not significant |

AP, acupuncture point; EA, electroacupuncture; GI, gastrointestinal; IBS, irritable bowel syndrome; SSc, scleroderma; TEAS, transcutaneous electrical acupoint stimulation.

3.7. Treatment of depression, addiction, and stroke

Two studies investigating the treatment of depression using LS,120,121 five studies evaluating the treatment of various addictions (i.e., alcoholism and addictions to tobacco and narcotics) using ES122–124 and LS,125,126 and four studies examining the treatment of stroke using ES127–130 are shown in Tables 7–9, respectively. LS was used by a research group to treat depression120,121, whereas two studies used ES devices123,124, one used LS125 to treat tobacco dependence, one used an ES device in the treatment of drug abuse,122 and one used LS to treat alcoholism.126 Five studies showed that the use of ES and that of LS for treating various addictions were appropriate treatment adjuncts. ES was applied for treating stroke in four studies. All the studies in which stroke was treated, including treatment with a combination therapy consisting of TEAS and task-related training, reported treatment efficacy of TEAS or EA based on clinical trials involving 421 individuals. These results showed that ES is feasible for treating stroke. All the studies in these three categories claimed beneficial effects on the treatment of depression, various addictions, or stroke.

3.8. Physiological changes, diverse diseases, miscellaneous characteristics, and brain activities

All the papers regarding ASDs that induced physiological changes, treated various diseases, affected miscellaneous characteristics, and induced brain activities are shown in Tables 10–13.131–174 respectively. Most studies in these categories were focused on phenomenological observations or consisted of a small number of clinical trials. Many more case studies are required to demonstrate the effects of ASDs on diverse diseases. These various investigations may expand the application of modern ASDs. Due to the limited scope of this review, we did not further investigate the diverse aspects of these studies.

4. Discussion

EAs, which are invasive types of ES, were the first and most intensively studied modern applications of ASDs. Recently, the number of publications regarding the clinical effectiveness of noninvasive stimulations, such as TEAS, LS, MS, and US, has been increasing (Fig. 3). The increase is more substantial for noninvasive acupuncture-like techniques, most likely due to the growing demands for painless acupuncture or acupoint stimulations. Among the 195 articles analyzed, the studies involving ES (EAs and TEAs) predominated (133 articles, 68%), followed by LS studies (44 articles, 23%). Studies involving MS (16 articles, 8%) or US (2 articles, 1%) were less common. The publication of ES studies has steadily increased since the early 2000s, whereas LS and MS showed similar increment patterns with delayed start-up points (i.e., the increases began in 2009 and 2011, respectively). Despite its long history, ES had a steady
Table 4 – Summary of studies on the effects of the four ASDs on nausea and vomiting

| Reference | Stimulation type | Stimulation site | Symptom | Control | Effect |
|-----------|------------------|------------------|---------|---------|--------|
| Xu et al96 | TEAS              | PC6              | PONV    | Prospective, blind, & randomized study, 119 patients, TEAS/sham TEAS | Prevention of PONV after infratentorial craniotomy |
| Wang et al97 | TEAS        | Right PC6        | Supratentorial craniotomy | Random TEAS (40)/control-nonacupoint (40), all standard general anesthesia | Prevalence of nausea, vomiting |
| Larson et al98 | TEAS        | Acupuncture points | Patients undergoing cosmetic surgery | Prospective, randomized, blinded, clinical trial, 122 patients, random standard pharm./pharm. + EA | Postoperative nausea & vomiting |
| Liu et al99 | TEAS            | Left-side PC6    | Patients undergoing laparoscopic cholecystectomy | 96 patients, random EA/placebo-EA no stim | Reduction of nausea & vomiting, pain relief |
| Habib et al100 | TEAS        | PC6/dorsum of wrist | Cesarean delivery with spinal anesthesia | Random, 91 patients, TEAS (47)/sham-APs TEAS (44) | No difference between the 2 groups (less PONV in 2 groups) |
| Kabalak et al100 | TEAS        | PC6, CV13        | Tonsillectomy under general anesthesia | Randomized, controlled, prospective study, 90 children, TEAS (30)/pharm. dose (30)/no treatment (30) | Prophylaxis of postoperative retching & vomiting in pediatric tonsillectomy |
| Kramer et al101 | TEAS        | PC6              | Patients receiving electroconvulsive therapy | 11 patients, TEAS (9 good, 1 mixed, 1 no response) | Treating nausea & vomiting |
| Rusy et al105 | EA            | PC6              | Tonsillectomy | 120 patients, random EA (40)/sham-EA sham needle (40)/control no needle (40) | PONV prevention |
| Zárate et al106 | TEAS        | PC6              | Laparoscopic cholecystectomy with standardized general anesthetic technique | Sham-controlled, double-blinded study, random, 221 outpatients, TEAS/placebo no stim | TEAS reduced postoperative nausea, but not vomiting |
| Shen et al106 | EA            | Antiemetic acupoints | High-risk breast cancer patients undergoing highly emetogenic chemotherapy regimen | 3-arm, parallel-group, randomized controlled trial, LF-EA (37)/mock-EA (33)/no-EA (34) | Effective in controlling emesis (EA > pharm.) |
| Schlager et al107 | LS          | Bi PC6           | Postoperative vomiting in children undergoing strabismus surgery | Double-blind, randomized, controlled study, 40 children, LS (20)/placebo (20) | Incidence of vomiting significantly lower |
| McMillan & Dundee104 | TEAS      | PC6              | Cancer chemotherapy | Antiemetic action, useful adjunct to both the older antiemetics & the new antagonist ondansetron |

ASD, acupuncture-like stimulation device; EA, electroacupuncture; LF, low frequency; PONV, postoperative nausea and vomiting; pharm, Pharmacological; stim, stimulation; TEAS, transcutaneous electrical acupoint stimulation.

but limited publication rate prior to 2000, whereas during the 1980s and 1990s, the number of publications on ES remained between zero article and two articles per year.

Fig. 4 shows the yearly publications of invasive (EAs) and noninvasive (TEASs) ES techniques. The total number of studies was similar between EAs (63 articles) and TEASs (70 articles). However, differences were observed in the number of publications per year; the publications associated with TEASs showed a steady increase over time, which is in contrast to the stable annual publication pattern of EAs. Notably, the number of TEAS publications surpassed that of EAs in 2010. Specifically, TEASs were studied more than EAs over the past 5 years in the context of diseases with high therapeutic benefits, such as analgesic effect, pain relief, improvement of the alimentary system, and prevention of nausea and vomiting. The rising popularity of TEASs is presumably due to the increasing needs...
### Table 5 – Summary of studies on the recovery of muscle fatigue or improvement of muscle strength with the four ASDs

| Reference | Stimulation type | Stimulation site | Symptom | Control | Effect |
|-----------|-----------------|-----------------|---------|---------|--------|
| Kim et al 108 | MS | LR9 | Healthy (males) | 20 participants (males), MS (10)/no MS (10) | Recovery of muscle fatigue |
| Kim et al 109 | TEAS/MS | An acupoint | Muscle fatigue | TEAS/MS/no stim | Therapeutic effect on muscle fatigue (MS better) |
| Zhou et al 110 | EA | ST36, ST39 | Healthy (males) | randomized controlled trial, 43 young men, control/MA/EA-APs/EA-non-APs | Improvement of muscle strength in both limbs |
| Ngai et al 111 | TEAS | Bi LU7, EX-B1 | Healthy (males) | 11 individuals (males), TEAS/placebo-TEAS no stim | Higher postexercise FEV1, prolongation of submaximal exercise |
| Huang et al 112 | EA | ST36, ST39 | Healthy (males) | 30 men, random EA/control | Improvement of muscle strength of both limbs |
| Chiu et al 113 | TEAS + LS/exercise + LS/LS | Acupoints | Chronic neck pain | Randomized clinical trial, 218 patients, TEAS + IR/Exercise + IR (LS)/IR | Improvement in disability, isometric neck muscle strength, pain (TEAS, exercise) |
| Milne et al 114 | TEAS/EA | LI4, LI11 | Healthy | TEAS/EA | Relief of muscle spasm & musculoskeletal pain, & restoration of mobility (TEAS) |

AP, acupuncture point; ASD, acupuncture-like stimulation device; EA, electroacupuncture; FEV1, forced expiratory volume in 1 second; IR, infrared; stim, stimulation; LS, laser stimulation; MA, manual acupuncture; MS, magnetic stimulation; TEAS, transcutaneous electrical acupoint stimulation.

### Table 6 – Summary of studies on the reduction in body weight with the four ASDs

| Reference | Stimulation type | Stimulation site | Symptom | Control | Effect |
|-----------|-----------------|-----------------|---------|---------|--------|
| Schukro et al 115 | AEA | 18, 87, 91 at ear | Obese females | Prospective, randomized, double-blinded study, 56 patients (females), AEA (28)/placebo dummy (28) | Reduction of body weight & BMI |
| Chien et al 116 | TEAS | ST36 | Postmenopausal obese women | Prospective study, 49 women, random TEAS (24)/placebo no-TEAS (25) | Reduction in percentage body fat |
| Rerksuppaphol & Rerksuppaphol 117 | TEAS/EA | 10 acupoints | Obese women | Prospective randomized open-label study, 45 women, TEAS/EA | Effective method for weight reduction as seen with EA |
| Lin et al 118 | EA | ST36, SP6 | Postmenopausal women with obesity | Randomized controlled trial, 41 women, EA (20)/control (21) | Improvement of body composition |
| Jeong & Lee 119 | EA | Acupoints | Factitial panniculitis | 2 cases (females), EA | Weight reduction |

AEA, auricular electroacupuncture; ASD, acupuncture-like stimulation device; EA, electroacupuncture; TEAS, transcutaneous electrical acupoint stimulation.

### Table 7 – Summary of studies on the treatment of depression with the four ASDs

| Reference | Stimulation type | Stimulation site | Symptom | Control | Effect |
|-----------|-----------------|-----------------|---------|---------|--------|
| Quah-Smith et al 120 | LS | LR14, LR8, CV14, HT7 | Depressed participants | Random block on-off design, 10 nondepressed participants, 10 depressed participants | Antidepressant effect |
| Quah-Smith et al 121 | LS | LR14, CV14, LR8, HT7, K13 | major depressive disorder | Randomized, double blinded, placebo controlled trial, 47 participants, LA/placebo LA | Reduction of symptoms of depression |

ASD, acupuncture-like stimulation device; LS, laser stimulation.
for safety without needling, low infection risk, and relatively expedient utilization of clinical trials. The recent increase in studies of LS and MS, which are noninvasive, may be understood based on the same rationale.

According to a recent analysis, approximately 41% of clinical studies in acupuncture research from 1991 to 2009 addressed pain and analgesia. Among the studies evaluating the four types of ASDs published through 2014, the percentage of clinical studies addressing pain and analgesia was 33%. This reduction in the percentage of studies focused on pain and analgesia is directly related to the recently heightened interest in acupuncture research on brain activities. The percentage of publications focused on brain activities that have been published since 2010 constitutes 61% (19 articles) of all such publications since 2001 (31 articles). Excluding the emerging category of brain activity, approximately 38%

Table 8 – Summary of studies on the treatment of smoking and addiction of drug and alcohol with the four ASDs

| Reference                | Stimulation type | Stimulation site | Symptom Control | Effect                                      |
|--------------------------|------------------|------------------|-----------------|---------------------------------------------|
| Penetar et al122         | TEAS             | PC6, TH5; LI4, PC8 | Cocaine dependent or cannabis dependent | Modulation of mood & anxiety, no significant reduction in drug use or drug cravings |
| Lambert et al123         | TEAS             | LI4, PC8, PC6, TE5 | Smoking         | Antagonizing the urge to smoke in dependent smokers |
| Kerr et al125            | LS               | 4 acupoints      | Smoking         | Assisting in smoking cessation by reducing the physical symptoms of withdrawal |
| Zalewska-Kaszubska & Obzejta126 | ALS             | Neck; 10 auricular acupoints | Alcoholics | Adjunct treatment for alcoholism |
| Georgiou et al124        | TEAS             | SJ18, SJ17       | Smoking cessation | Insufficient power to detect real but small differences between treatment conditions |

ALS, auricular laser stimulation; ASD, acupuncture-like stimulation device; f, female; LS, laser stimulation; m, male; stim, stimulation; ST, standard treatment; TEAS, transcutaneous electrical acupoint stimulation.

Table 9 – Summary of studies on the treatment of stroke with the four ASDs

| Reference                 | Stimulation type | Stimulation site | Symptom Control | Effect                                      |
|---------------------------|------------------|------------------|-----------------|---------------------------------------------|
| Ng & Hui-Chan127          | TEAS + TRT       | ST36, LV3, GB34, UB60 | Poststroke      | Decreased impairment & improved function in an individual with long-term chronic stroke |
| Gong et al128             | EA               | ST36             | First-time cerebral infarction or hemorrhage, or a stroke history | Effects on lower extremity motor function in stroke patients |
| Kim et al129              | TEAS             | Acupoints        | Ischemic stroke with motor dysfunction | Helpful for motor recovery after ischemic stroke (LF-TEAS) |
| Wong et al130             | TEAS             | Acupoints        | Patients with hemiplegia in stroke | Convenient & effective therapy for stroke |

ASD, acupuncture-like stimulation device; EA, electroacupuncture; LF, low frequency; TEAS, transcutaneous electrical acupoint stimulation; TRT, task-related training.
Table 10 – Summary of studies on physiological changes with the four ASDs

| Reference       | Stimulation type | Stimulation site | Symptom                  | Control                        | Effect                                                                 |
|-----------------|------------------|------------------|--------------------------|--------------------------------|------------------------------------------------------------------------|
| Cafaro et al    | LS               | Bi LI2, ST5, ST6, ST7, SI19, BL 13 LI4 | Sjögren's syndrome       | 26 female, patients, LA/sham LA | Salivary flow rate improvement                                         |
| Kim et al       | MS               |                  |                          |                                | Improvement of peripheral vascular system circulation                  |
| Li et al        | EA               | L4, TE5, BL63, LR3, ST36, BL40, BL10, BL20, BL2, EX-HN4 | Supratentorial craniotomy   | 29 patients, control (10)/EA (9)/sham EA (10) | Prevention of decrease of immunoglobulin after surgery, no significant difference between EA & sham EA |
| Litscher et al  | LS               | GV20, PC6        | Healthy                  | Randomized crossover study, 11 volunteers (3 m, 8 f), MA/GV20;PC6/red LA (GV20;PC6)/violet LA (GV20;PC6) | HR & HRV control                                                        |
| Tsuruoka et al  | US               | LR3              | Healthy                  | 50 volunteers (40 m, 10 f), random US/MA | Increase of blood flow volume                                           |
| Wang et al      | LS               | Right L14        | Healthy                  | 28 volunteers, random LA-L14/LA-non L14 | Increase of left L14 MBF, 40 min later after stimulation ceased, the MBF still increasing significantly |
| Raith et al     | LS               | L14              | Premature neonates       | 10 neonates (7 m, 3 f), initial temp/5 min stim temp/10 min stim temp | Increase in the skin temperature                                        |
| Lee et al       | MS               | PC9              | Healthy                  | 1 individual                    | Parasympathetic activity of the autonomic nervous system               |
| Jia et al       | EA               | BI ST36, ST37    | Healthy                  | 20 volunteers, EA/sham EA       | Effect on autonomic function                                            |
| Jones et al     | TEAS             | Bilateral PC6    | Healthy                  | 16 volunteers, random TEAS/sham-TEAS non-APs/no TEAS no-stim | Change in artery                                                        |
| Lee et al       | EA               | L14, L111        | Healthy                  | Randomized crossover design, 14 participants, HF-EA 120 Hz/LF-EA 2 Hz | Increase in autonomic nervous activity (HF-EA), enhancing sympathovagal balance (both) |
| Chang et al     | EA               | ST36, L110       | Healthy                  | 15 volunteers, LF EA (low freq. 2 Hz)/HF EA (high freq. 100 Hz) | Not affecting cardiovagal activity in normal volunteers                 |
| Cunha et al     | LS/MA            | 10 acupoints     | Circulatory deficiency   | 40 individuals, LS (20)/MA (20) | Significant increase in systolic pressure of lower limbs, consequent improvement of the revascularization index |
| Litscher et al  | LS               | PC6              | Healthy                  | Randomized, controlled study, 13 volunteers, LS/control-laser off | Decrease of HR                                                         |
| Kim et al       | EA               | MS, EA, TENS     | Healthy                  | 20 volunteers, random sham-MA/MA/EA/TENS; before-A, during-A, after-A (time sequence) | EGG, ECG, HR change                                                   |
| Lu et al        | MA, EA, TENS     | Bi ST36, ST37, palm, dorsum | Healthy                  | 20 volunteers, random sham-MA/MA/EA/TENS; before-A, during-A, after-A (time sequence) | Cutaneous blood flow & temperature change                             |
| Zhang et al     | TEAS             | L14, L111        | Normal & elevated blood pressure | Randomly, 27 individuals, TEAS (13, 8 m, 5 f)/control (14, 9 m, 5 f) | Reduction of systolic blood pressure, but not diastolic blood pressure |
| Zhang et al     | LS               | L14, L111        | Healthy                  | Randomized controlled pilot study, 45 students + faculty, LA/sham-LA laser off | Reduction of blood pressure                                           |
| Cakmak et al    | EA               | ST29, ST25       | Healthy (m)              | Prospective, randomized study, 80 volunteers, MA/2 Hz-EA/10 Hz-EA | Increase in testicular blood flow, helpful in clinical treatment of infertile men (ST29, 10 Hz) |
| Reference          | Stimulation type | Stimulation site | Symptom                | Control                                                                 | Effect                                                                 |
|-------------------|------------------|------------------|------------------------|-------------------------------------------------------------------------|-------------------------------------------------------------------------|
| Arai et al.       | TEAS             | Bi PCS, PC6/shoulder | Parturients undergoing cesarean section under spinal anesthesia | Random, 36 singleton parturients, TEAS (12)/sham-APs TEAS (12)/no treatment (12) | Reduction of the severity & incidence of hypotension after spinal anesthesia in parturients |
| Cheung & Jones    | TEAS             | Bilateral PC6    | Healthy (m)            | Single-blinded, randomized controlled trial, 28 individuals, treadmill, TEAS/pre-TEAS/placebo-TEAS | HR recovery after exercise                                               |
| Banzer et al.     | LS               | Right forearm PC6 | Healthy (nonsmoking males) | Randomized, double-blinded, placebo-controlled trial, 33 healthy (m), LA (18)/control no laser (15) | Improvement of blood flow                                               |
| Szeles & Litscher | AEA              | Ear acupuncture points | Healthy (f)           | 2 healthy (f), AEA                                                       | Modulation of blood flow                                                |
| Litscher          | LS               | Acupuncture points | Healthy                | Randomized crossover study, 22 volunteers, LS                          | Changes in peripheral microcirculation & surface temperature of skin     |
| Li et al.         | MS (magnitopuncture) | GV14, PC6         | Healthy (m)            | Randomly, 40 individuals, MS/control MS non-APs                         | Modulating effect on sympathetic & parasympathetic nerve activities       |
| Hsieh et al.      | EA               | ST36              | Healthy                | 8 volunteers, before/during/after EA                                    | Physiological mechanisms responsible increases of blood flow in ophthalmic artery |
| Litscher & Schikora | LS            | Vision-related acupoints | Healthy               | Randomized crossover trial, 27 volunteers (13 m, 14 f), LA/MA          | Increases of blood flow in posterior cerebral artery                    |
| Cramp et al.      | TENS/TEAS        | Median nerve/Li4  | Healthy                | Randomly, 30 individuals (15 m, 15 f), control (10)/TENS (10)/TEAS (10) | Increase in cutaneous blood flow in the TENS median nerve               |
| Litscher et al.   | LS               | Vision-related acupoints | Healthy               | 15 volunteers (10 m, 5 f), LS/MA                                       | Increases in blood flow velocity in posterior cerebral artery           |
| Balogun et al.    | TEAS (HVG)       | ST36, ST37        | Healthy                | 11 individuals (5 m, 6 f), 2 Hz-TEAS/120 Hz-TEAS                        | No increase in peripheral hemodynamic functions in asymptomatic individuals |
| Williams et al.   | TEAS             | LR3, ST36, Li11, SP6, LR3 | Diastolic hypertension Pregnant women | Random, 10 individuals, TEAS/sham-TEAS non-APs. Randomly, TEAS/control no stim | Reduction of diastolic blood pressure for TEAS Increase in frequency & strength of uterine contractions |
| Dunn et al.       | TEAS             |                  |                        |                                                                         |                                                                         |

AEA, auricular electroacupuncture; AP, acupuncture point; ASD, acupuncture-like stimulation device; EA, electroacupuncture; ECG, electrocardiogram; EEG, electroencephalogram; f, female; HF, high frequency; HR, heart rate; HRV, heart rate variability; HVG, high voltage galvanic; LA, laser acupuncture; LF, low frequency; LS, laser stimulation; m, male; MA, manual acupuncture; MBF, meridian blood flow; MS, magnetic stimulation; stim, stimulation; TEAS, transcutaneous electrical acupoint stimulation; TENS, transcutaneous electrical nerve stimulation; US, ultrasound stimulation.

of the studies were focused on pain and analgesia, which is similar to the percentage of MA studies focused on pain and analgesia.

The effectiveness analysis showed that the effectiveness of ES with respect to the analgesic effect, pain relief, and reduction of nausea and vomiting was confirmed by clinical trials involving > 1000 individuals and many RCTs. Based on clinical trials involving > 100 individuals, ES was effective in improving the alimentary system, improving muscle strength, reducing body weight, and treating stroke. Likewise, LS was shown to be useful for providing pain relief and in treating various addictions. Interestingly, the addiction treatment effect was confirmed by LS studies but not by ES studies.

4.1. Limitations

Our review is based on the four most influential databases, specifically Medline, PubMed, Cochrane Library, and Web of Science; moreover, we primarily analyzed Science Citation Index (SCI) or Science Citation Index Expanded (SCI-E) journal articles. The advantage of this approach is the inclusion of quality-guaranteed articles only. Laboratory experiments on animals, MA-only clinical trials, non-English-language articles, and review articles were excluded from the analysis. The details regarding device specifications or interventional designs, including stimulation strength, duration and interval, and patient and environmental conditions, were not analyzed due to space limitations.
| Reference                | Stimulation type | Stimulation site                  | Symptom                                      | Control                                         | Effect                                                                                     |
|--------------------------|------------------|-----------------------------------|----------------------------------------------|------------------------------------------------|---------------------------------------------------------------------------------------------|
| Sun et al142              | EA               | Bilateral PC6                    | OI                                           | Randomized, controlled, crossover design, EA (20)/no EA (10) | Treatment in attenuating OI                                                                |
| Zhang et al196            | TEAS             | LI4, PC6, ST36, SP6              | Autistic children receiving rehabilitation training | 76 children, TEAS (37)/no treatment (39) | Effective for treatment of autistic children with passive & aloof social interaction style |
| Yang et al197             | TEAS             | LI4, SJ5, ST36, BL63, LR3, GB40  | Supratentorial craniotomy                     | Randomized controlled trial, EA/sham-EA        | Significantly shortened speed of postoperative recovery                                    |
| Sahmeddini et al198       | EA               | PC6, PCS                        | End-stage liver disease patients undergoing orthotopic deceased donor liver transplantation | Randomized, 40 patients, norepinephrine-vasoconstrictor/EA | Reduction of severity & incidence of hypotension during anesthesia for liver transplantation |
| Ng et al199               | TEAS             | Bi PC6                          | Open heart surgery                           | 40 patients, random TEAS (20)/placebo-TEAS no stim (20) | Earlier return to preoperative BP, HR, & RPP values                                        |
| Wang et al200             | MA/EA            | Bi GB8, TE17, GB2, GB20, GV20, TE3, ST36 (MA)/bi GB8, TE17 (EA) | Tinnitus                                      | Randomized, single-blinded, placebo-controlled design, 50 patients (46 m, 4 f), MA/EA/placebo | Short-term general effects on tinnitus (EA)                                                |
| O’Brien et al201          | LS               | 10 acupoints                     | Active symptoms of menopause                  | Double-blind, randomized, placebo-controlled study, 40 women, LS/placebo LS (off) | Treatment of menopausal symptoms (no more efficacious than MA)                             |
| Ngai et al202             | TEAS             | Bi EX-B1, LU7                   | Patients with asthma                          | Randomized controlled trial, 30 individuals, random TEAS/TEAS + ST/sham-TEAS + ST | Reduction in the decline of forced expiratory volume in 1s FEV (1) following exercise training |
| Burduli & Ranyuk203       | LS + ST          | Acupuncture points               | Chronic noncalculous cholecystitis            | 73 patients, ST (35)/LA + ST (38) | Cholecystitis treatment                                                                    |
| Su et al204               | LS               | Acupoints                        | Renal failure patients receiving regular hemodialysis | Randomized controlled trial, before/after LS | Decrease in both stress & fatigue levels                                                   |
| Lau & Jones205            | TEAS             | Bi Ex-B1                        | Chronic obstructive pulmonary disease         | Randomized, placebo-controlled trial, 46 patients, TEAS/placebo-TEAS no stim | Management of dyspnea                                                                      |
| Hsu et al206              | EA               | BL15                             | Healthy                                       | 10 volunteers, sham-EA/2 Hz-EA                 | Relaxation, calmness, & reduced feeling of tension or distress                           |
| Bray et al207             | EA               | Uni PC6, HT3, LR3/bi GB34, LI11, SI13 | Healthy                                      | 80 individuals, EA-PC6, HT3, LR3/EA/GB34, LI11, SI13/no stim; 5/60/100 Hz; uni/bilateral | Adjunct therapy for disorders of hypervigilance (to decrease arousal levels)             |
| Litscher et al208         | LS               | ST7, TE22                        | Intensive care patient after severe head injury | 34 volunteers (10 m, 24 f), 1 patient (head injury), acupuncture/MA/LA | Reproducible functional changes in the brain                                                |
| O’Reilly et al209         | LS               | SP6                              | Interstitial cystitis                         | Double-blind trial, random LS (29)/placebo (27) | Treatment & control cohorts experiencing similar improvements, no difference between active & sham |
| Li et al210               | MS               | GV14, PC6                        | Healthy                                       | Randomly, 40 individuals, MS/control MS non-APs | Effects of driving fatigue                                                                |

AP, acupuncture point; ASD, acupuncture-like stimulation device; BP, blood pressure; EA, electroacupuncture; f, female; FEV1, forced expiratory volume in 1 second; HR, heart rate; LA, laser acupuncture; LS, laser stimulation; m, male; MA, manual acupuncture; MS, magnetic stimulation; OI, orthostatic intolerance; RPP, rate pressure product; ST, standard treatment; stim, stimulation; TEAS, transcutaneous electrical acupoint stimulation.
### Table 12 – Clinical studies showing miscellaneous characteristics

| Reference          | Stimulation type | Stimulation site                                      | Symptom Control | Effect                                                      |
|--------------------|------------------|-------------------------------------------------------|------------------|------------------------------------------------------------|
| Chen et al \(^{143}\) | LS               | LU9, PC7, HT7, SI4, SJ4, L5, SP3, LR3, KI4, BL65, GB40, ST42 | Healthy          | 76 candidates Complementary & interaction for current flow of meridians |
| Gopalan et al \(^{211}\) | EA               | Implanted with cardiac device                         | Healthy          | Safety in patients with a total artificial heart          |
| Irnich et al \(^{212}\) | LS/Seirin (sham-LS) | LI4, LU7, LR3                                           | Healthy          | Valid placebo control in laser acupuncture studies (Seirin) |
| Litscher & Wang \(^{213}\) | MA/LS            | LU6                                                   | Healthy          | Changes of electrical skin impedance                      |
| Thompson & Cummings \(^{214}\) | EA               | Acupuncture points in a limb                          | Healthy          | No detectable currents in the chest (safety)              |
| Leung et al \(^{215}\) | TEAS/MA/EA       | LI4                                                   | Healthy          | Difference in electrical conductance between APs & non-APs |
| Litscher et al \(^{216}\) | LS               | Acupuncture points                                    | Healthy          | Change in the median value of cold pain, no significant changes in parameters of thermal sensory & pain thresholds |
| Chang et al, \(^{217}\) | EA/TEAS          | Left LI4                                              | Healthy          | Changes of cutaneous reflex                               |

AP, acupuncture point; EA, electroacupuncture; f, female; LA, laser acupuncture; LS, laser stimulation; m, male; MA, manual acupuncture; TEAS, transcutaneous electrical acupoint stimulation.

---

**Fig. 3 – The number of published articles on the four ASDs per year.**

ASD, acupuncture-like stimulation device; ES, electrical stimulation; LS, laser stimulation; MS, magnetic stimulation; US, ultrasound stimulation.
| Reference                  | Stimulation type | Stimulation site | Symptom       | Control                                                                 | Effect                          |
|----------------------------|------------------|------------------|---------------|--------------------------------------------------------------------------|---------------------------------|
| Guo et al.                 | MS               | PC6              | Healthy       | 6 right-handed volunteers (3 m, 3 f)                                     | Brain activity                  |
| Raith et al.               | LS               | Left GE37        | Healthy       | GB37-MS/mock point-MS                                                   | Brain activity                  |
| Quah-Smith et al.          | LS               | LR8              | Healthy       | 16 participants, random on-off block design, LA/MA                       | Brain activity                  |
| Zhang et al.               | TEAS             | LI4, PC8         | Healthy       | 18 individuals (9 m, 9 f), all individuals TEAS                          | Brain activity                  |
| Zhang et al.               | MS               | PC6              | Healthy       | —                                                                         | Brain activity                  |
| Lee et al.                 | MS               | PC9              | Healthy       | —                                                                         | HRV & brain activity            |
| Litscher                   | LS               | PC6              | Healthy       | 40 volunteers, LA/MA                                                     | Brain activity                  |
| Wu et al.                  | LS               | Palm             | Healthy       | single-blind randomized trial, 40 individuals (m), random LS (20)/sham LS (20) | Brain activity                  |
| Litscher et al.            | LS               | BI PC6           | Healthy (f)   | 1 volunteer (f), LA                                                     | Brain activity                  |
| Yu et al.                  | LS               | LI4, PC8         | Healthy       | 40 individuals, TEAS (40)                                                | Brain activity                  |
| Hsieh et al.               | LS               | KI1              | Healthy right handed | 36 right-handed volunteers, random MW LA (12; 8 m, 4 f)/CW LA (12; 9 m, 4 f/placebo LA(12) | Brain activity                  |
| Yu et al.                  | MS               | PC6              | Healthy       | —                                                                         | Brain activity                  |
| Kim et al.                 | MS               | PC9              | Healthy       | —                                                                         | Vascular & brain activity       |
| Jo & Jo                    | MS               | HT4, HT6         | Healthy       | 23 young adults (aged 19–22 y)                                           | Brain activity (pole direction)  |
| Zyloney et al.             | EA               | LI3, LI4 right hand | Healthy, right handed | 48 individuals, random EA/sham EA                                     | Brain activity                  |
| Quah-Smith et al.          | LS               | LR14, CV14, LR8, HT7 | Healthy      | 10 individuals, random LA/LA-sham point                                    | Brain activity                  |
| Xu et al.                  | MS               | ST36, LI4        | Healthy       | MS/MS-mock point                                                         | Brain activity                  |
| Xu et al.                  | EA               | GB34             | Healthy       | 12 individuals, EA/EA-sham points,                                        | Brain activity                  |
| An et al.                  | EA               | LI4, LI11        | Healthy       | Brain SPECT EA (20)/PET EA (13); before/during /after EA                 | Brain activity                  |
| Wang et al.                | EA               | Right LI4        | Healthy       | EA (9)/sham-point EA (5)                                                 | Brain activity                  |
| Zeng et al.                | EA               | LI4              | Healthy (right handed) | 23 volunteers (m), EA-TE8 (11)/EA-GV15 (6) | Brain activity                  |
| Litscher et al.            | LS               | Acupoints        | Healthy       | Randomized controlled crossover trial, 18 volunteers (7 m, 11 f), before/during-LA/after LA | Modulation of blood flow, brain activity |
| Zhang et al.               | EA               | Left leg ST36, SP6 | Healthy (right handed) | 48 individuals, 2 Hz-EA/100 Hz-EA                                       | Analgesia effect/brain activity |
| Li et al.                  | EA               | TE8, GV15        | Healthy (Chinese males)       | 17 volunteers (m), EA-TE8 (11)/EA-GV15 (6) | Brain activity, typical language areas in the left inferior frontal cortex not activated |
| Kong et al.                | EA               | Left hand LI4    | Healthy (right handed) | 11 volunteers (6 m, 5 f), EA/MA                                       | Brain activity                  |
| Siedentopf et al.          | LS               | Left foot BL67   | Healthy (m)   | 10 volunteers (m), LA/dummy LA                                           | Brain activity                  |
| Wu et al.                  | EA               | GB34             | Healthy       | random, control TEAS no stim/MA/2 Hz/TEAS/100 Hz/TEAS                   | Increases in amplitude of H-reflex (TEAS), 100 Hz TEAS has greater effect |
| Chang et al.               | MA/TEAS          | LI4              | Healthy       |                                                                           |                                 |

AP, acupuncture point; ASD, acupuncture-like stimulation device; EA, electroacupuncture; f, female; HRV, heart rate variability; LA, laser acupuncture; LS, laser stimulation; m, male; MA, manual acupuncture; MS, magnetic stimulation; PET, positron emission tomography; SPECT, single-photon emission computed tomography; stim, stimulation; TEAS, transcutaneous electrical acupoint stimulation.
Fig. 4 – The number of articles on ES methods with years, where EAs include the invasive techniques of EA, AEA, and EHA, and TEASs include the noninvasive techniques of TEAS and TENS. AEA, auricular electroacupuncture; EA, electroacupuncture; EHA, electrical heat acupuncture; ES, electrical stimulation; TEAS, transcutaneous electrical acupoint stimulation; TENS, transcutaneous electrical nerve stimulation.

5. Conclusions

In the past decade, modern ASDs have been studied extensively for their clinical effectiveness and to test equivalence or noninferiority with traditional MA. Among the modern ASDs, ES was found to be most widely studied, and its popularity was sequentially followed by LS, MS, and US. Specifically, EAs, which are invasive types of ES, were the first and most intensively studied types of ASDs, whereas TEASs, which are noninvasive types of ES, have surpassed EAs in publication number since 2010. Very recently, noninvasive techniques, such as TEASs, LS, MS, and US have gained research attention, as evidenced by increasing annual publications.

The most extensively studied treatment effects were for analgesia and pain relief, whereas rapid growth has occurred in the research field of the effects of treatments on brain activities. The overall quality of the study designs was moderate, as 58% of the studies were based on RCTs and 96% of the RCT-based outcomes reported therapeutic benefits. ES was effective in providing an analgesic effect, pain relief, and a reduction of nausea and vomiting, based on clinical trials involving > 1000 individuals. Based on > 100 clinical trials, ES was shown to be effective in improving the alimentary system, improving muscle strength, reducing body weight, and treating stroke. LS was effective in pain relief and for treating various addictions. We anticipate more studies on the therapeutic effects of ASDs, particularly concerning noninvasive methods, to meet the growing needs of guaranteed safety, decreased risk of infection, decreased pain, and improved convenience.

Conflicts of interest

No conflicts of interest are declared.

Acknowledgments

This work was supported by a grant (K15012) from the Korea Institute of Oriental Medicine, Daejeon, Korea, funded by the Korean government.

References

1. World Health Organization. Acupuncture: review and analysis of reports on controlled clinical trials. Geneva, Switzerland: World Health Organization; 2002.
2. Choi SM, Park JE, Li SS, Jung H, Zi M, Kim TH, et al. A multicenter, randomized, controlled trial testing the effects of acupuncture on allergic rhinitis. Allergy 2013;68:365–74.
3. Paramore LC. Use of alternative therapies: estimates from the 1994 Robert Wood Johnson Foundation National Access to Care Survey. J Pain Symptom Manage 1997;13:83–9.
4. Helms JM. Acupuncture energetics: a clinical approach for physicians. Berkeley: Thieme Medical Acupuncture Publishers; 1995.
5. NIH Consensus Conference. Acupuncture. JAMA 1998;280:1518–24.
6. Han JS. Acupuncture analgesia: areas of consensus and controversy. Pain 2011;152(3 Suppl):S41–8.
7. Voll R. Twenty years of electroacupuncture diagnosis in Germany. A progress report. Am J Acupunct 1975;3:7–17.
26. Lan F, Ma YH, Xue JX, Wang TL, Ma DQ. Transcutaneous electroacupuncture: a systematic review. Bioelectromagnetics 2008;29:245–56.

27. Cheing GL, Chan WW. Influence of choice of electrical parameters on postoperative opioid analgesia requirement. Anesth Analg 2008;97:623–9.

28. Greif R, Lacy S, Mokhtaran M, Doufas AG, Bakhshandeh M, Dorfer L, et al. Transcutaneous electrical stimulation of an auricular acupuncture point decreases anesthetic requirement. Anesthesiology 2002;96:306–12.

29. Chen L, Tang J, White PF, Sloninsky A, Wender RH, Naruse R, et al. The effect of location of transcutaneous electrical nerve stimulation on postoperative opioid analgesic requirement: acupoint versus nonacupoint stimulation. Anesth Analg 1998;87:1129–34.

30. Wang L, Tang J, White PF, Naruse R, Sloninsky A, Kariger R, et al. Effect of the intensity of transcutaneous acupoint electrical stimulation on the postoperative analgesic requirement. Anesth Analg 1997;85:406–13.

31. Wu J, Zhao Y, Yang G, Xu Q, Li N. Effects of electroacupuncture preemptive intervention on postoperative pain of mixed herniorrhoids. Zhongguo Zhen Jiu (Chin Acupunct Moxibustion) 2014;34:279–83.

32. Zheng X, Meng J-B, Fang Q. Electroacupuncture reduces the dose of midazolam monitored by the bispectral index in critically ill patients with mechanical ventilation: an exploratory study. Anesth Analg 2012;114:78–84.

33. Barlas P, Ting SLH, Chesterton LS, Jones PW, Sim J. Effects of intensity of electroacupuncture upon experimental pain in healthy human volunteers: a randomized, double-blind, placebo-controlled study. Pain 2006;122:81–9.

34. Zhang WT, Jin Z, Huang J, Zhang L, Zeng YW, Luo F, et al. Modulation of cold pain in human brain by electric acupoint stimulation: evidence from fMRI. Neuroreport 2003;14:1591–6.

35. Morioka N, Aka O, Doufas AG, Chernyak G, Sessler DI. Electro-acupuncture at the Zusanli, Yanglingquan, and Tanying points does not reduce anesthetic requirement. Anesth Analg 2002;95:98–102.

36. Leung A, Khadivi B, Duann JR, Cho ZH, Yaksh T. The effect of Ting point (tendinomuscular meridians) electroacupuncture on thermal pain: A model for studying the neuronal mechanism of acupuncture analgesia. J Altern Complement Med 2005;11:653–61.

37. Lin JG, Lo MW, Wen YR, Hsieh CL, Tsai SK, Sun WZ. The effect of high and low frequency electroacupuncture in pain after lower abdominal surgery. Pain 2002;99:509–14.

38. Litscher G. Effects of acupressure, manual acupuncture and laser acupuncture on EEG bispectral index and spectral edge frequency in healthy volunteers. Eur J Anaesth 2004;21:13–9.

39. Brockhaus A, Elger CE. Hypalgesic efficacy of acupuncture on experimental pain in man. Comparison of laser acupuncture and needle acupuncture. Pain 1990;43:181–5.

40. Mucuk S, Baser M. Effects of noninvasive electroacupuncture on labour pain and duration. J Clin Nurs 2014;23:1603–10.

41. Sun C, Hu C, Hao H, Niu C, Li L. Development of a uni-acupoint transcutaneous electric nerve stimulation device for electroacupuncture-like neuromodulation. In: Conference proceedings: Annual International Conference of the IEEE Engineering in Medicine and Biology Society IEEE
dental pain test. Review of possible mechanisms of action. *Acupunct Electrother Res* 1986;12:5–22.

77. Srbely JZ, Dickey JP, Lowerson M, Edwards AM, Nolet PS, Wong LL. Stimulation of myofascial trigger points with ultrasound induces segmental antinociceptive effects: a randomized controlled study. *Pain* 2008;139:260–6.

78. Kempf D, Berger D, Ausfeld-Hafter B. Laser needle acupuncture in women with dysmenorrhoea: a randomised controlled double blind pilot trial. *Forsch Komplementmed* 2009;16:6–12.

79. Aigner N, Fialka C, Radda C, Vecsei V. Adjuvant laser acupuncture in the treatment of whiplash injuries: a prospective, randomized placebo-controlled trial. *Wien Klin Wochenschr* 2006;118:95–9.

80. Naeser MA, Hahn KAK, Lieberman BE, Branco KF. Carpal tunnel syndrome pain treated with low-level laser and microamperes transcutaneous electric nerve stimulation: a controlled study. *Arch Phys Med Rehabil* 2002;83:978–88.

81. Takamjani IE, Marouf N, Amoli MJ, Nia SHS. The effect of low power LASER acupuncture on experimental pain threshold in normal subjects. *Caspian J Intern Med* 2010;1:145–8.

82. Glazov G, Schattner P, Lopez D, Shandley K. Laser acupuncture for chronic non-specific low back pain: a controlled clinical trial. *Acupunct Electrother Res* 2009;34:94–100.

83. King CE, Clelland JA, Knowles CJ, Jackson JR. Effect of helium–neon laser therapy. *Phys Ther* 1990;70:24–30.

84. Waylonis GW, Jones AYM, Ng SSM, Wong CYN, Lee JFY. Prolonged treatment with transcutaneous electrical acupoint stimulation of the acupoint P6 reduces postoperative vomiting in patients after laparoscopic cholecystectomy. *Chin J Integr Med* 2008;14:94–7.

85. Liu YY, Duan SE, Cai MX, Zou P, Lai Y, Li YL. Evaluation of transcutaneous electroacupoint stimulation with the train-of-four mode for preventing nausea and vomiting after laparoscopic cholecystectomy. *Chin J Integr Med* 2008;14:94–7.

86. Habib AS, Itchon-Ramos N, Phillips-Bute BG, Gan TJ. Transcutaneous acupoint electrical acupoint stimulation with the ReliefBand for the prevention of nausea and vomiting during and after cesarean delivery under spinal anesthesia. *Anesth Analg* 2006;102:581–4.

87. Zárate E, Mingus M, White PF, Chiu JW, Scuderi P, Loskota W, et al. The use of transcutaneous acupoint electrical stimulation in preventing nausea, vomiting, and pain in outpatient plastic surgery patients: a prospective, randomized, blinded, clinical trial. *Plastic Reconst Surg* 2010;125:989–94.

88. Habib AS, Itchon-Ramos N, Phillips-Bute BG, Gan TJ. Transcutaneous acupoint electrical acupoint stimulation with the ReliefBand for the prevention of nausea and vomiting during and after cesarean delivery under spinal anesthesia. *Anesth Analg* 2006;102:581–4.

89. Sallam H, McNearney TA, Doshi D, Chen JDZ. Adjuvant laser acupuncture for chronic non-specific low back pain: a controlled clinical trial. *Acupunct Electrother Res* 2009;34:94–100.

90. Liu S, Peng S, Hou X, Ke M, Chen JDZ. Transcutaneous electroacupuncture improves dyspeptic symptoms and increases high frequency heart rate variability in patients with functional dyspepsia. *Neurogastroenterol Motil* 2008;20:1204–11.

91. Chang CS, Chou JW, Ko CW, Wu CY, Chen GH. Cutaneous electrical stimulation of acupuncture points may enhance gastric myoelectrical regularity. *Digestion* 2002;66:106–11.

92. Zou D, Chen WH, Iwakiri K, Rigda R, Tippett M, Holloway RH. Inhibition of transient lower esophageal sphincter relaxations by electrical acupoint stimulation. *Am J Physiol Gastrointest Liver Physiol* 2005;289:197–201.
109. Kim SB, Kim JY, Park SW, Lee NR, Lee SW, Kim YH, et al. Comparison of 2 methods of non-invasive treatment between transcutaneous electrical stimulation and pulsed electromagnetic field stimulation as replacement of invasive manual acupuncture. *Acupunct Electrother Res* 2012;37:247–61.

110. Zhou S, Huang LP, Liu J, Yu JH, Tian Q, Cao LJ. Bilateral effects of 6 weeks’ unilateral acupuncture and electroacupuncture on ankle dorsiflexors muscle strength: a pilot study. *Arch Phys Med Rehabil* 2012;93:50–5.

111. Ngai SPC, Jones AYM, Hui-Chan CWY. Acu-TENS and postexercise expiratory flow volume in healthy subjects. *Evid Based Complement Altern Med* 2011;2011:1–7.

112. Huang LP, Zhou S, Lu Z, Tian Q, Li X, Cao LJ, et al. Bilateral effect of unilateral electroacupuncture on muscle strength. *J Altern Complement Med* 2007;13:539–46.

113. Chiu TTW, Hui-Chan CWY, Cheing G. A randomized clinical trial of TENS and exercise for patients with chronic neck pain. *Clin Rehabil* 2005;19:850–60.

114. Milne RJ, Dawson NJ, Butler MJ, Lippold OCJ. Intramuscular acupuncture-like electrical stimulation inhibits stretch reflexes in contralateral finger extensor muscles. *Exp Neurol* 1985;90:96–107.

115. Schukro RP, Heiserer C, Michalek-Sauberer A, Gleiss A, Sator-Katzenschlager S. The effects of auricular electroacupuncture on obesity in female patients—a prospective randomized placebo-controlled pilot study. *Complement Ther Med* 2014;22:21–5.

116. Chien LW, Lin MH, Chung HY, Liu CF. Transcutaneous electrical stimulation of acupoints changes body composition and heart rate variability in postmenopausal women with obesity. *Evid Based Complement Altern Med* 2011;2011:626121.

117. Kerr CM, Lowe PB, Spielholz NI. Low level laser for the antidepressant effect of laser acupuncture: a comparison to electroacupuncture. *Lasers Med Sci* 2009;24:117–22.

118. Lin CH, Lin YM, Liu CF. Electrical acupoint stimulation changes body composition and the meridian systems in postmenopausal women with obesity. *Am J Chin Med* 2010;38:683–94.

119. Jeong KH, Lee MH. Two cases of factitial panniculitis induced by electroacupuncture. *Clin Exp Dermatol* 2009;34:E170–3.

120. Quah-Smith I, Suo C, Williams M, Sachdev P. The antidepressant effect of laser acupuncture: a comparison of the resting brain’s default mode network in healthy and depressed subjects during functional magnetic resonance imaging. *Med Acupunct* 2013;25:124–33.

121. Quah-Smith I, Smith C, Crawford JD, Russell J. Laser acupuncture for depression: a randomised double blind controlled trial using low intensity laser intervention. *J Affect Disord* 2013;148:179–87.

122. Penetar DM, Burgos-Robles A, Trksak GH, MacLean RR, Dunlap S, Lee DW, et al. Effects of transcutaneous electric acupoint stimulation on drug use and responses to cue-induced craving: a pilot study. *Chin Med (UK)* 2012;7:1–10.

123. Lambert C, Berlin I, Lee TL, Hee SW, Tan ASL, Picard D, et al. A standardized transcutaneous electric acupoint stimulation for relieving tobacco urges in dependent smokers. *Evid Based Complement Altern Med* 2011;2011:195714.

124. Georgiou AJ, Spencer CF, Davies GK, Stamp J. Electrical stimulation therapy in the treatment of cigarette smoking. *J Subst Abuse* 1998;10:265–74.

125. Kerr CM, Lowe PB, Spielholz NI. Low level laser for the stimulation of acupoints for smoking cessation: a double blind, placebo controlled randomised trial and semi structured interviews. *J Chin Med* 2008;46:46-51.

126. Zalewska-Kaszubska J, Obzejta D. Use of low-energy laser as adjunct treatment of alcohol addiction. *Lasers Med Sci* 2004;19:100–4.

127. Ng SSM, Hui-Chan CWY. Transcutaneous electrical stimulation on acupoints combined with task-related training to improve motor function and walking performance in an individual 7 years poststroke: a case study. *J Neurol Phys Ther* 2010;34:208–13.

128. Gong W, Zhang T, Cui L, Yang Y, Sun X. Electro-acupuncture at Zusanli (ST 36) to improve lower extremity motor function in sensory disturbance patients with cerebral stroke: a randomized controlled study of 240 cases. *Neural Regen Res* 2009;4:935–40.

129. Kim YS, Hong JW, Na BJ, Park SU, Jung WS, Moon SK, et al. The effect of low versus high frequency electrical acupoint stimulation on motor recovery after ischemic stroke by motor evoked potentials study. *Am J Chin Med* 2008;36:45–54.

130. Wong AM, Su TY, Tang FT, Cheng FT, Liaw MY. Clinical trial of electrical acupuncture on hemiplegic stroke patients. *Exp Neurol* 1999;158:117–22.

131. Cafaro A, Arduino PG, Gambino A, Romagnoli E, Broccoli E. R. Effect of laser acupuncture on salivary flow rate in patients with Sjögren’s syndrome. *Lasers Med Sci* 2015;30:1805–9.

132. Litscher G, Wang L, Wang X, Gaischek I. Laser acupuncture: two acupoints (Baihui, Neiguan) and two modalities of laser (658 nm, 405 nm) induce different effects in neurovegetative parameters. *Evid Based Complement Altern Med* 2013;2013:432764.

133. Wang G, Tian Y, Jia S, Litscher G, Zhang W. Evaluate laser needle effect on blood perfusion signals of contralateral Hegu acupoint with wavelet analysis. *Evid Based Complement Altern Med* 2012;2012:103729.

134. Raith W, Litscher G, Sapetschnig I, Bauchinger S, Ziehenberger E, Mueller W, et al. Thermographical measuring of the skin temperature using laser needle acupuncture in preterm neonates. *Evid Based Complement Altern Med* 2012;2012:614210.

135. Litscher G, Xie Z, Wang L, Gaischek I. Blue 405 nm laser light modulates heart rate—investigations at the acupoint Neiguan (Pe 6) in Chinese adults. *North Am J Med Sci* 2009;1:226–31.

136. Litscher G, Marquina N, Ozinos G, Sau A, Ng D. Effect of laser acupoint treatment on blood pressure and body weight—a pilot study. *J Chiropr Med* 2008;7:134–9.

137. Banzer W, Huebscher M, Seib M, Vogt L. Short-time effects of laser needle stimulation on the peripheral microcirculation assessed by laser Doppler spectroscopy and near-infrared spectroscopy. *Photomed Laser Surg* 2006;24:575–80.

138. Litscher G. Cerebral and peripheral effects of Laserneedle-stimulation. *Neural Res* 2003;25:722–8.

139. Litscher G, Schikora D. Cerebral vascular effects of non-invasive laserneedles measured by transorbital and transtemporal Doppler sonography. *Lasers Med Sci* 2002;17:289–95.

140. Cunha RG, Rodrigues KC, Salvador M, Zangaro RA. Effectiveness of laser treatment at acupuncture sites compared to traditional acupuncture in the treatment of peripheral artery disease. In: *Engineering in Medicine and Biology Society (EMBC), 2010 Annual International Conference of the IEEE*. 2010:1262–5.
141. Litscher G, Wang L, Wiesner-Zechmeister M. Specific effects of laserpuncture on the cerebral circulation. Lasers Med Sci 2009;24(5):57–62.

142. Sun J, Sang H, Yang C, Dong H, Lei C, Lu Y, et al. Electroacupuncture improves orthostatic tolerance in healthy individuals via improving cardiac function and activating the sympathetic system. Europace 2013;15:127–34.

143. Chen CW, Tai CJ, Choy CS, Hsu CY, Lin SL, Chan WP, et al. Wave-induced flow in meridians demonstrated using photoluminescent bioceramic material on acupuncture points. Evid Based Complement Altern Med 2013;2013:739293.

144. Guo L, Wang Y, Yu H, Yin N, Li Y. Study of brain functional network based on sample entropy of EEG under magnetic stimulation at PC5 acupoint. Biomed Mater Eng 2014;24:1063–9.

145. Zhang X, Fu LD, Geng YH, Zhai X, Liu YH. Analysis of the effect of repeated-pulse transcranial magnetic stimulation at the Gungming point on electroencephalograms. Neural Regen Res 2014;9:549–54.

146. Raith W, Pichler G, Sapetschnig I, Avian A, Sommer C, Baik et al. Analysis of the brain effects of laser acupuncture in healthy individuals: an fMRI investigation. PloS One 2010;5:e12619.

147. Xu G, Zhang X, Yu H, Ho SL, Yang Q, Fu WN, et al. Complexity analysis of EEG under magnetic stimulation at acupoints. IEEE Trans Appl Supercond 2010;20:1029–32.

148. Na B-J, Jangh G-H, Park S-U, Jung W-S, Moon S-K, Park J-M, et al. An fMRI study of neuronal specificity of an acupoint: Electroacupuncture stimulation of Yanglingquan (GB34) and its sham point. Neurosci Lett 2009;464:1–5.

149. Xu G, Zhang X, Ho SL, Fu WN, Yan W, Yang W. Complexity analysis of magnetic stimulation at the acupoint of Zusanli (ST36) on EEG. IEEE Trans Magn 2009;45:4829–32.

150. An Y-S, Moon S-K, Min I-K, Kim D-Y. Changes in regional cerebral blood flow and glucose metabolism following electroacupuncture at LI 4 and LI 11 in normal volunteers. J Altern Complement Med 2009;15:1075–81.

151. Zhang W, Liu L, Zhu X, Huang J-B, Liu D-X, Wang H, et al. Study on the regulatory effect of electro-acupuncture on Hegu point (LI 14) in cerebral response with functional magnetic resonance imaging. Chin J Integr Med 2007;13:10–6.

152. Litscher G. Laser acupuncture-innovative basic research: visual and laser-induced evoked potentials. Laser Ther 2012;21:287–95.

153. Wu JH, Chang WD, Hsieh CW, Jiang JA, Fang W, Shan YC, et al. Effect of low-level laser stimulation on EEG. Evid Based Complement Altern Med 2012;2012:951272.

154. Litscher G, Baumerfeind G, Mueller-Putz G, Neuper C. Laser-induced evoked potentials in the brain after nonperceptible optical stimulation at the Neiguan acupoint: a preliminary report. Evid Based Complement Altern Med 2012;2012:292475.

155. Zeng Y, Liang X-C, Dai J-P, Wang Y, Yang Z-L, Li M, et al. Electroacupuncture modulates cortical activities evoked by noxious somatosensory stimulations in human. Brain Res 2006;1097:90–100.

156. Litscher G, Rachbauer D, Roepste S, Wang L, Schikora D, Fazekas I, et al. Acupuncture using laser needles modulates brain function: first evidence from functional transcranial Doppler sonography and functional magnetic resonance imaging. Lasers Med Sci 2004;19:6–11.

157. Zhang WT, Jin Z, Cui GH, Zhang KL, Zhang L, Zeng YW, et al. Relations between brain network activation and algogenic effect induced by low vs. high frequency electrical acupoint stimulation in different subjects: a functional magnetic resonance imaging study. Brain Res 2003;982:168–78.

158. Wu MT, Sheen JM, Chuang KH, Yang P, Chin SL, Tsai CY, et al. An fMRI study comparing brain activation between word generation and electrical stimulation of language-implicated acupoints. Hum Brain Map 2003;18:233–8.

159. Jo HG, Jo GH. Electroencephalogram activity induced by magnetic stimulation on heart meridian. Neurosci Lett 2011;495:107–9.

160. Zylone CE, Jensen K, Polich G, Loiotille RE, Cheetham A, LaViolette PS, et al. Imaging the functional connectivity of the Periaqueductal Gray during genuine and sham electroacupuncture treatment. Mol Pain 2010;6:80 [11p].

161. Quah-Smith I, Sachdev PS, Wen W, Chen X, Williams MA. The brain effects of laser acupuncture in healthy individuals: an fMRI investigation. PloS One 2010;5:e12619.
low level laser stimulus: motivation for blood flow increase using stimulus on acupoint LI4 (Hegu). J Magn 2014;19:32–6.

176. Li G, Li S, Wang B, An L. The effect of electroacupuncture on postoperative immunoinflammatory response in patients undergoing supratentorial craniotomy. Exp Ther Med 2013;6:699–702.

177. Tsuruoka N, Watanabe M, Takayama S, Seki T, Matsunaga T, Haga Y. Brief effect of acupoint stimulation using focused ultrasound. J Altern Complement Med 2013;19:416–9.

178. Lee J, Hwang DG, Yoo JS, Lee HS. Analysis of electroencephalogram and electrocardiogram at an acupoint PC9 during pulsed magnetic field stimulus. J Magn 2012;17:133–7.

179. Jia BA, Cheng CY, Lin Y-W, Li T-C, Liu H-J, Hsieh C-L. The 2 Hz and 15 Hz electroacupuncture induced reverse effect on autonomic function in healthy adult using a heart rate variability analysis. J Tradit and Complement Med 2011;1:51–6.

180. Jones AYM, Kwan YL, Leung NTF, Yu RPW, Wu CMY, Warburton DER. Electrical stimulation of acupoint locations and blood pressure responses to postural changes: a pilot study. Am J Crit Care 2011;20:E67–74.

181. Lee JH, Kim KH, Hong JW, Lee WC, Koo S. Comparison of electroacupuncture frequency-related effects on heart rate variability in healthy volunteers: a randomized clinical trial. J Acupunct Meridian Stud 2011;4:107–15.

182. Chang CS, Ko C-W, Lien H-C, Chou M-C. Effect of electroacupuncture on St. 36 (Zusanli) and LI 10 (Shousanli) acupuncture points on heart rate variability. Am J Chin Med 2010;38:231–9.

183. Kim MS, Cho YC, Moon JH, Pak SC. A characteristic estimation of bio-signals for electro-acupuncture stimulations in human subjects. Am J Chin Med 2009;37:505–17.

184. Lu C-C, Jan Y-M, Li T-C, Hsieh C-L. Electroacupuncture induces differential effects between Yin and Yang: a study using cutaneous blood flow and temperature recordings of the hand’s dorsum and palm. Am J Chin Med 2009;37:639–45.

185. Zhang J, Ng D, Sau A. Effects of electrical stimulation of acupuncture points on blood pressure. J Chiropr Med 2009;8:9–14.

186. Cakmak YO, Akpinar IN, Ekinci G, Bekiroglu N. Point- and frequency-specific response of the testicular artery to abdominal electroacupuncture in humans. Fertil Steril 2008;90:1732–8.

187. Arazi YC, Kato N, Matsuura M, Ito H, Kandatsu N, Kurokawa S, et al. Transcutaneous electrical nerve stimulation at the PC-5 and PC-6 acupoints reduced the severity of hypotension after spinal anaesthesia in patients undergoing caesarean section. Br J Anaesth 2008;100:78–81.

188. Cheung LC-T, Jones AYM. Effect of Acu-TENS on recovery heart rate after treadmill running exercise in subjects with normal health. Complement Ther Med 2007;15:109–14.

189. Szollosi JC, Litscher G. Objectivation of cerebral effects with a new continuous electrical auricular stimulation technique for pain management. Neurol Res 2004;26:797–800.

190. Li Z, Jiao K, Chen M, Wang C. Effect of magnitopuncture on sympathetic and parasympathetic nerve activities in healthy drivers—assessment by power spectrum analysis of heart rate variability. Eur J Appl Physiol 2003;88:404–10.

191. Hsieh CL, Wu CHW, Lin JG, Chiu CC, Chen M, Hsieh CT. The physiological mechanisms of 2 Hz electroacupuncture: a study using blink and H reflex. Am J Chin Med 2002;30:369–78.

192. Cramp AF, Noble JG, Lowe AS, Walsh DM. Transcutaneous electrical nerve stimulation (TENS): the effect of electrode placement upon cutaneous blood flow and skin temperature. Acupunct Electrother Res 2000;26:25–37.

193. Balogun JA, Tang S, He Y, Hsieh JM, Katz JS. Effects of high-voltage galvanic stimulation of ST36 and ST37 acupuncture points on peripheral blood flow and skin temperature. Disabil Rehabil 1996;18:523–8.

194. Williams T, Mueller K, Cornwall MW. Effect of acupuncture-point stimulation on diastolic blood pressure in hypertensive subjects: a preliminary study. Phys Ther 1991;71:523–9.

195. Dunn PA, Rogers D, Halford K. Transcutaneous electrical nerve stimulation at acupuncture points in the induction of uterine contractions. Obstet Gynecol 1989;73:286–90.

196. Zhang R, Jia MX, Zhang JS, Xu XJ, Shou XJ, Zhang XT, et al. Transcutaneous electrical acupoint stimulation in children with autism and its impact on plasma levels of arginine-vasopressin and oxytocin: a prospective single-blinded controlled study. Res Dev Disabil 2012;33:1136–46.

197. Yang C, An L, Han R, Kang X, Wang B. Effects of combining electroacupuncture with general anesthesia induced by sevoflurane in patients undergoing supratentorial craniotomy and improvements in their clinical recovery profile & blood enkephalin. Acupunct Electrother Res 2012;37:125–38.

198. Sahmeedlind MA, Eghbal MH, Ghaffaripour S, Manatfakran M, Shokoue S. Electroacupuncture stimulation at acupoints reduced the severity of hypotension during anesthesia in patients undergoing liver transplantation. J Acupunct Meridian Stud 2012;5:11–4.

199. Ng MCS, Jones AYM, Cheng LC. The role of Acu-TENS in hemodynamic recovery after open-heart surgery. Evid Based Complement Altern Med 2011;2011:301974.

200. Wang K, Bugge J, Bugge S. A randomised, placebo-controlled trial of manual and electrical acupuncture for the treatment of tinnitus. Complement Ther Med 2010;18:249–55.

201. O’Brien KA, Vargas E, Black C, Komesaroff PA. Laser acupuncture does not improve menopausal symptoms. Menopause 2010;17:636–41.

202. Ngai SPC, Jones AYM, Hui-Chan CWY, Ko FWS, Hui DSC. Effect of Acu-TENS on post-exercise expiratory lung volume in subjects with asthma—a randomized controlled trial. Respir Physiol Neurobiol 2009;167:348–53.

203. Burduli NM, Ranyuk LG. Effects of laser reflex therapy on a motor function of the gall bladder and physical properties of bile in patients with chronic acalculous cholecystitis. Ter Arkh 2009;81:57–61.

204. Su LH, Wu KD, Lee LS, Wang H, Liu CF. Effects of far infrared acupoint stimulation on autonomic activity and quality of life in hemodialysis patients. Am J Chin Med 2009;37:215–26.

205. Lau KSL, Jones AYM. A single session of Acu-TENS increases FEV1 and reduces dyspnoea in patients with chronic obstructive pulmonary disease: a randomised, placebo-controlled trial. Aust J Physiother 2008;54:179–84.

206. Hsu CC, Weng CS, Liu TS, Tsai YS, Chang YH. Effects of electrical acupuncture on acupoint BL15 evaluated in terms of heart rate variability, pulse rate variability and skin conductance response. Am J Chin Med 2006;34:23–36.

207. Bray PA, Mamiya N, Fann AV, Gellman H, Skinner RD, Garcia-Rill EE. Modulation of the sleep state-dependent P50 conductance response. Brain Res 2005;105:85–90.

208. Litscher G, Wang L, Schwarz G, Schikora D. Increases of the autonomic function with a heart rate variability analysis. J Tradit and Complement Med 2011;1:51–6.

209. Ng MCS, Jones AYM, Cheng LC. The role of Acu-TENS in hemodynamic recovery after open-heart surgery. Evid Based Complement Altern Med 2011;2011:301974.

210. Wang K, Bugge J, Bugge S. A randomised, placebo-controlled trial of manual and electrical acupuncture for the treatment of tinnitus. Complement Ther Med 2010;18:249–55.

211. O’Brien KA, Vargas E, Black C, Komesaroff PA. Laser acupuncture does not improve menopausal symptoms. Menopause 2010;17:636–41.

212. Ngai SPC, Jones AYM, Hui-Chan CWY, Ko FWS, Hui DSC. Effect of Acu-TENS on post-exercise expiratory lung volume in subjects with asthma—a randomized controlled trial. Respir Physiol Neurobiol 2009;167:348–53.

213. Litscher G, Wang L, Schwarz G, Schikora D. Increases of the autonomic function with a heart rate variability analysis. J Tradit and Complement Med 2011;1:51–6.
therapy is not effective in women with interstitial cystitis. J Urol 2004;172:1880–3.

210. Li Z, Jiao K, Chen M, Wang C. Reducing the effects of driving fatigue with magnitopuncture stimulation. Accid Anal Prev 2004;36:501–5.

211. Gopalan R, Scott R, Arabia F, Chandrasekaran K. Electro-acupuncture therapy in a patient with a total artificial heart. Acupunct Med 2011;29:302–3.

212. Irnich D, Salih N, Offenbacher M, Fleckenstein J. Is sham laser a valid control for acupuncture trials? Evid Based Complement Altern Med 2011;2011:485945.

213. Litscher G, Wang L. Biomedical engineering meets acupuncture—development of a miniaturized 48-channel skin impedance measurement system for needle and laser acupuncture. Biomed Eng Online 2010;9:78.

214. Thompson JW, Cummings M. Investigating the safety of electroacupuncture with a Picoscope™. Acupunct Med 2008;26:133–9.

215. Leung AY, Park J, Schulteis G, Duann J-R, Yaksh T. The electrophysiology of de qi sensations. J Altern Complement Med 2006;12:743–50.

216. Litscher G, Wang L, Huber E, Schikora D, Schwarz G. Quantification of gender specific thermal sensory and pain threshold before and after laserneedle stimulation. Biomed Tech 2004;49:106–10.

217. Chang QY, Lin JG, Hsieh CL. Effect of electroacupuncture and transcutaneous electrical nerve stimulation at Hegu (LI4) acupuncture point on the cutaneous reflex. Acupunct Electrother Res 2002;27:191–202.