

Herbal infusions and health

A review of findings from human studies, mechanisms and future research directions

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Abstract

Purpose – Increasingly, interest in and the uptake of herbal infusions has advanced, namely, owing to their bioactive properties and potential links to health. Given this, the purpose of the present review was to collate evidence from human trials for five popular herbal infusions.

Design/methodology/approach – The systematic review comprised ten human trials (560 participants), investigating inter-relationships between herbal infusions consumption and health. Only human studies involving German chamomile (*Matricaria chamomilla* L. Asteraceae), ginger (*Zingiber officinale* Roscoe Zingiberaceae), lemon balm (*Melissa officinalis* L. Lamiaceae), peppermint (*Mentha x spicata* L. Lamiaceae)/spearmint (*Mentha spicata* L. Lamiaceae) and rosehip (*Rosa canina* L. Rosaceae) teas were included in the present paper.

Findings – Most herbal infusions serve as a good source of flavonoids and other polyphenols in the human diet. Studies included in this paper indicate that herbal infusions (1-3 cups tended to be drunk daily; infusion rates up to 15 min) could benefit certain aspects of health. In particular, this includes aspects of sleep quality and glycaemic control (German chamomile), osteoarthritic stiffness and hormone control (spearmint), oxidative stress (lemon balm) and primary dysmenorrhea (rosehip).

Research limitations/implications – Ongoing research is needed using homogenous herbal infusion forms, brewing rates and volumes of water to further reinforce these findings. In the meantime, herbal infusions could provide a useful supplementary approach to improving certain aspects of well-being.

Originality/value – The present paper collates evidence from human trials for five popular herbal infusions.

Keywords Anti-oxidants, Health, Herbal infusions, Polyphenols, Tisanes

Paper type Literature review

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Introduction

Herbal infusions have long been used in traditional medicine and are a popular global beverage choice (Poswal *et al.*, 2019). Now, in the era of globalisation, regional and ethnic barriers have been removed and specialist infusions have become universally available (Chandrasekara and Shahidi, 2018). For example, in the UK, herbal infusions account for approximately 36 per cent of all varieties consumed (Mintel, 2019).

The consumption of herbal beverages is gaining popularity driven by the fact that many are rich sources of natural bioactive compounds, such as alkaloids, carotenoids, coumarins, flavonoids, polyacetylenes and terpenoids (Chandrasekara and Shahidi, 2018). Subsequently, more people consume these infusions as daily beverages for health purposes (Li *et al.*, 2013). The aphorism that “Nature is the best chemist” has a long historic pedigree (Abuhamdahab and Chazota, 2008).

Accruing evidence suggests that bioactives present in herbals infusions could have a diverse range of biological effects, including potential anti-bacterial, anti-oxidant, anti-inflammatory, anti-allergic, anti-thrombotic and vasodilatory actions, as well as anti-mutagenic, anti-carcinogenic and anti-ageing effects (Chandrasekara and Shahidi, 2018). The Rotterdam cohort comprised 2,424 adults, found that herbal tea consumers (36.3 per cent) had reduced levels of liver stiffness – a proxy for liver fibrosis, which was independent of several other lifestyle and environmental factors (Alferink *et al.*, 2017).

Increasingly, more people are beginning to take control of their own health. For example, the European Social Survey found that complementary and alternative medicine (CAM) treatments were used by 25.9 per cent of the general population with women and those with a higher level of education more likely to use these (Kemppainen *et al.*, 2018). In another study, 80 per cent of 480 respondents from German General Practitioner practices were more likely to use home remedies before using pharmaceutical products – these included hot lemon drinks and chamomile tea (Parisius *et al.*, 2014). Recently, it was also purported that herbal tea phytochemicals could have synergistic potential, helping to manage medical conditions when used alongside conventional medicines (Malongane *et al.*, 2017).

Given the shift towards integrated medicine and growing interest in herbal infusions and health, the present review collates evidence from human trials and mechanistic studies to better understand inter-relationships between herbal infusions and health. A recent scoping review collating evidence from 21 studies (including observational studies) showed that herbal tea consumption could confer some preventative and clinical benefits (Poswal *et al.*, 2019).

In the present review, we focus on five specific herbal infusions: chamomile (*Matricaria chamomilla* L. Asteraceae), ginger (*Zingiber officinale* Roscoe Zingiberaceae), lemon balm (*Melissa officinalis* L. Lamiaceae), peppermint (*Mentha x spicata* L. Lamiaceae)/spearmint (*Mentha spicata* L. Lamiaceae) and rosehip (*Rosa canina* L. Rosaceae) teas and evidence from human trials, although we also support this with mechanistic studies.

Materials and methods

A literature search was conducted to identify human trials examining inter-relationships between herbal infusions and markers of health. A National Centre for Biotechnology Information (PubMed) search was undertaken to identify these studies using the selection filter.

Filters were applied to extract English language publications. Search terms applied were: “herbal tea/infusion/tisane”, “chamomile tea/infusion/tisane”, “ginger tea/infusion/tisane”, “lemon balm/*Melissa officinalis* tea/infusion/tisane”, “peppermint/spearmint tea/infusion/tisane” and “rosehip/rose tea/infusion/tisane”. The filter was set to only identify human

clinical trials. The reference lists of relevant publications were also searched. Relevant mechanistic studies were also discussed for each of the herbal tea forms to supplement evidence.

Data extracted from each article included the following:

- author and country of research;
- study population (number of participants, age, gender and health status at baseline);
- study design;
- the intervention applied (dose/cups of herbals tea provided);
- infusion conditions (length of time, water temperature);
- health outcomes; and
- study findings ([Table I](#)).

Publications were excluded, if they were not one of the named five infusions or were multiple/combined interventions, e.g. two herbal teas extracts or pilot studies. Studies were also omitted where capsules/supplements of concentrated sources of herbal extracts were used rather than “tea” as infusions or in beverage form. When full texts were not available, these were purchased. Latin binomials were checked using the Kew Medicinal Plant Names Services database (www.mpns.science.kew.org).

Data extraction

The present review followed the preferred reporting items for systematic reviews and meta-Analyses (PRISMA) statement ([Moher et al., 2009](#)). Publications were omitted, if PRISMA benchmarks were not included in the trial publication but instead published elsewhere. Relevant data extracted from the studies included the amount of herbal infusions given within the intervention and compliance. The Jadad scale and criteria was then applied and used to develop quality scores for each human trial ([Jadad et al., 1996](#)). Quality scores were graded between 1 and 5 with higher scores being indicative of higher quality ([Table II](#)).

Results

The PubMed search identified 264 publications. Of these, 254 papers were discarded after reviewing the abstracts and article content, as they did not meet the inclusion criteria. This left ten human trials for general review. The algorithm of qualifying publications is shown in [Figure 1](#).

Of these, three studies were conducted in Taiwan, China ([Chang and Chen, 2016](#); [Chao et al., 2011](#); [Tseng et al., 2005](#)) three in Iran ([Zemestani et al., 2016](#); [Rafraf et al., 2015](#); [Zeraatpishe et al., 2011](#)) and one in Turkey ([Akdogan et al., 2007](#)), Japan, ([Yui et al., 2017](#)) Canada ([Connelly et al., 2014](#)) and the UK ([Grant, 2010](#)). Of the ten studies identified, seven were good quality and ranking 3 or higher on the Jadad scale ([Table II](#)) ([Chang and Chen, 2016](#); [Zemestani et al., 2016](#); [Rafraf et al., 2015](#); [Yui et al., 2017](#); [Connelly et al., 2014](#); [Grant, 2010](#); [Tseng et al., 2005](#)).

German chamomile tea

German chamomile (*Matricaria chamomilla* L. *Asteraceae*) should not be confused with Roman chamomile [*Chamaemelum nobile* (L.) *Asteraceae*]. It is one of the most ancient and popular single ingredient herbal teas known to man ([McKay and Blumberg, 2006a](#)). From a historical perspective, chamomile has been used to help ease ailments such as hay fever, inflammation, muscle spasms, menstrual disorders, insomnia, ulcers, gastrointestinal

Table I.
Human studies
investigating herbal
tea consumption and
health

Tea infusions (author, year, location)	Population (sample size, age, gender, health)	Study design	Herbal tea intervention	Infusion conditions	Health outcomes studies	Key findings
<i>Chamomile</i> Chang and Chen (2016) Taiwan	<i>n</i> = 80 Taiwanese postnatal women with poor sleep quality	2-week RCT	One 300 ml cup daily for 14 days (each teabag provided 2 g dried flowers; German origin)	Infused in 300 ml hot water for 0-15 min	Sleep, depression EPDS PFS PSQS	The tea group demonstrated significantly ↓ scores of physical symptoms-related sleep inefficiency (<i>P</i> = 0.015) and symptoms of depression (<i>P</i> = 0.020) compared to the control. Positive effects were limited to the immediate term (2 weeks)
Zamestani et al. (2016) Iran	<i>n</i> = 64 T2 DM (M and F) 30 to 60 yrs	8-week SB RCT	Three 3 g/150 ml cups daily. Consumed immediately after meals or water as a control	Infused in 150 ml water without milk or sugar for 10 min	Glycaemic control, antioxidant status	Chamomile tea significantly ↓ concentration of glycosylated haemoglobin, serum insulin levels, HOMA and serum malondialdehyde compared with the control (all <i>P</i> < 0.05). Total antioxidant capacity, superoxide dismutase, glutathione peroxidase and catalase activities significantly ↑ in chamomile group compared with the control (all <i>P</i> < 0.05)
Rafrat et al. (2015) Iran	<i>n</i> = 64 T2 DM (M and F) 30-60 yrs	8-week SB RCT	Three 3 g/150 ml cups daily. Consumed immediately after meals or water as a control	Infused in 150 ml water without milk or sugar for 10 min	Glycaemic control, antioxidant status	Chamomile tea significantly ↓ concentrations of HbA1C (<i>P</i> = 0.03), serum insulin levels (<i>P</i> < 0.001), HOMA (<i>P</i> < 0.001), total cholesterol (<i>P</i> = 0.001), triglyceride (<i>P</i> < 0.001), and low-density lipoprotein cholesterol (<i>P</i> = 0.05) compared with the control

(continued)

Tea infusions (author, year, location)	Population (sample size, age, gender, health)	Study design	Herbal tea intervention	Infusion conditions	Health outcomes studies	Key findings
Ginger Chao <i>et al.</i> (2011) Taiwan	<i>n</i> = 30 subjects with heat and non-heat constitutions 21-31 yrs	<i>In vivo</i> trial. Subjects repeated this 3x taking different samples (water, aged ginger tea or coconut water) each time, at one-week intervals	One 250 ml cup daily. Sliced aged ginger (18.75 g) was added into water (800 ml). Coconut water was given or water as a control	250 ml infusion provided after 20 min of boiling	Pulse rate	Stroke volume ↑ and pulse pressure ↓ in the non-heat constitution subjects after taking aged ginger tea
Lenon balm Yui <i>et al.</i> (2017) Japan	<i>n</i> = 28 healthy Japanese adults 31-64 yrs	6-week open-label parallel-group comparative trial	One 200 ml cup daily. 3.3 g LB leaves or barley tea grams (control) were placed in non-women fabric bags	Infused in 200 ml of hot water (about 95°C) and steeped for 5 min	Pulse wave velocity, arterial stiffness, forearm skin colour	The LB group showed significant ↓ in brachial-ankle pulse wave velocity, reflecting arterial stiffness, and forearm skin colour compared with the control. LB extract in hot water could ↓ glycation-associated tissue damage in blood vessels and skin of healthy adults
Zeraatpishe <i>et al.</i> (2011) Iran	<i>n</i> = 55 radiology staff	30-day before-after clinical trial	Two 1.5 g/100 ml cups daily. LB leaves packed in 1.5 g tea bags	Infused 1.5 g LB tea bags in 100 ml 98 °C water for 30 min	Oxidative stress status in radiology staff that were exposed to persistent low-dose radiation during work	LB infusions markedly improve oxidative stress condition and DNA damage. The LB infusion led to a significant improvement in plasma levels of catalase, superoxide dismutase, and glutathione peroxidase and a ↓ in plasma DNA damage, myeloperoxidase, and lipid peroxidation

(continued)

Table I.

Table I.

Tea infusions (author, year, location)	Population (sample size, age, gender, health)	Study design	Herbal tea intervention	Infusion conditions	Health outcomes studies	Key findings
<i>Peppermint/spearmint</i> Comnelly et al. (2014) Canada	<i>n</i> = 46 participants (mean age = 60.7 yrs) with medically diagnosed OA of the knee	16-week randomised, parallel-arm, DB study	One 300 ml cup daily. Participants in the control and high-rosA groups consumed 26 versus 280 mg rosA per day	1 tea bag was to be steeped in 300 ml boiling water for 5 min with occasional stirring. The addition of milk, cream, sugar, or sweetener was not allowed	Walk and stair climb tests	Daily consumption of the high rosA and commercial spearmint teas significantly improved stiffness and physical disability scores in adults with knee OA, but only the high-rosA tea significantly ↓ pain
Grant (2010) UK	<i>n</i> = 42 F with PCOS and hirsutism. 19-42 yrs	Dual centre, 30 day RCT	Two cups daily. Allocated to drink spearmint tea twice a day for a 1 month period or a placebo herbal chamomile tea (has no endocrine disrupting properties)	Infusion time not reported	Degree of hirsutism. DQLI (score of 0-30)	Free and total testosterone levels significantly ↓ over the 30 day period in the spearmint tea group (<i>P</i> < 0.05). LH and FSH ↑ (<i>P</i> < 0.05). Patient's subjective assessments of their hirsutism significantly ↓ in the spearmint tea group (<i>P</i> < 0.05) After 5-days of drinking spearmint tea FT significantly ↓ (from 5.49-3.92 pg/ml) <i>P</i> < 0.05 and there was significant ↑s in: LH (6.34-8.04 mIU/ml), FSH (4.56-5.36 mIU/ml) and E ₂ (46.5-63.4 pg/ml, <i>P</i> < 0.05). Triglyceride levels also significantly ↓ (95.9-86.4 mg/dL, <i>P</i> < 0.05) after drinking spearmint tea
Akdogan et al. (2007) Turkey	<i>n</i> = 21. PCOS or idiopathic hirsutism cases. 18-40 yrs	5-day trial during the follicular phase of the MC	Two 250 ml steeped Mentha spicata (% 20 g/L) cups daily	A cup of boiling water was poured over 1 heaped US teaspoon (5 g) dried leaves and steeped for 5-10 min	Fasting blood samples	

(continued)

Tea infusions (author, year, location)	Population (sample size, age, gender, health)	Study design	Herbal tea intervention	Infusion conditions	Health outcomes studies	Key findings
<i>Rosehip</i> <i>Tseng et al.</i> (2006) Taiwan	130 female adolescents, ≈16 yrs	RCT for 6 MCs	Two 300 ml cups daily Participants drank rose tea for 1 week before their menstrual period until the 5 th menstrual day for 6-cycles. The control had no intervention	6 dry rosebuds infused in 300 ml hot water for 10 minutes	SF-MPQ; MSQ-SF; PLAS; PSS; VASA	After rose tea consumption females perceived less menstrual pain, distress, anxiety and had improved psychophysiological wellbeing at 1,3 and 6 months

Notes: Key: DB, double-blind; DNA, Deoxyribonucleic Acid; DQLI, Dermatology Quality of Life Index; EPDS, Edinburgh Postnatal Depression Scale; E₂, Oestradiol; F, Female; FSH, Follicle Stimulating Hormone; FT, Free Testosterone; HbA1C, Haemoglobin A1c; HOMA, Homeostatic Model Assessment for Insulin Resistance; LB, Lemon Balm; M, Male; MC, Menstrual Cycle; MSQ-SF, Menstrual Distress Questionnaire-Short Form; LH, Luteinizing Hormone; OA, osteoarthritis; PFS, Postpartum Fatigue Scale; PLAS, Psychophysiological Life Adaptation Scale; PSS, Perceived Stress Scale; PSQS, Postpartum Sleep Quality Questionnaire; RCT, Randomised Controlled Trial; SB, Single Blind; PCOS, Polycystic Ovary Syndrome; SF-MPQ, Short Form McGill Pain Questionnaire; T2DM, Type 2 Diabetes Mellitus; VASA, Visual Analogue Scale for Anxiety; VASP, Visual Analogue Scale for Pain; ↓ reduced, ↑ increased; yrs, years

Table I.

Table II.
Assessment scale
used to assess trial
quality

Publication	Randomisation	Method of randomisation described and appropriate	Blinding mentioned	Method of blinding described and appropriate	Withdrawal and dropout of subjects provided	Total score
<i>Chamomile</i>						
Chang and Chen (2016) Taiwan	Y	N	Y (single)	N	Y	3
Zemestani <i>et al.</i> (2016) Iran	Y	Y	Y (single)	Y	Y	5
Rafraf <i>et al.</i> (2015) Iran	Y	Y	Y (single)	Y	Y	5
<i>Ginger</i>						
Chao <i>et al.</i> (2011) Taiwan	Y	N	N	N	Y	2
<i>Lemon Balm</i>						
Yui <i>et al.</i> (2017) Japan	Y	Y	N	N	Y	3
Zeraatpishe <i>et al.</i> (2011) Iran	N	N	N	N	N	0
<i>Peppermint/Spearmint</i>						
Connelly <i>et al.</i> (2014) Canada	Y	Y	Y (double)	Y	Y	5
Grant (2010) UK	Y	Y	Y (single)	Y	Y	5
Akdogan <i>et al.</i> (2007) Turkey	N	N	N	N	Y	1
<i>Roselhip</i>						
Tseng <i>et al.</i> (2005) Taiwan	Y	Y	N	N	Y	3

Notes: Total quality assessment score for which scores range between 1 and 5: with 1 being the lowest quality and 5 being the highest quality. 3 = above average quality; Key: Y, yes; N, no

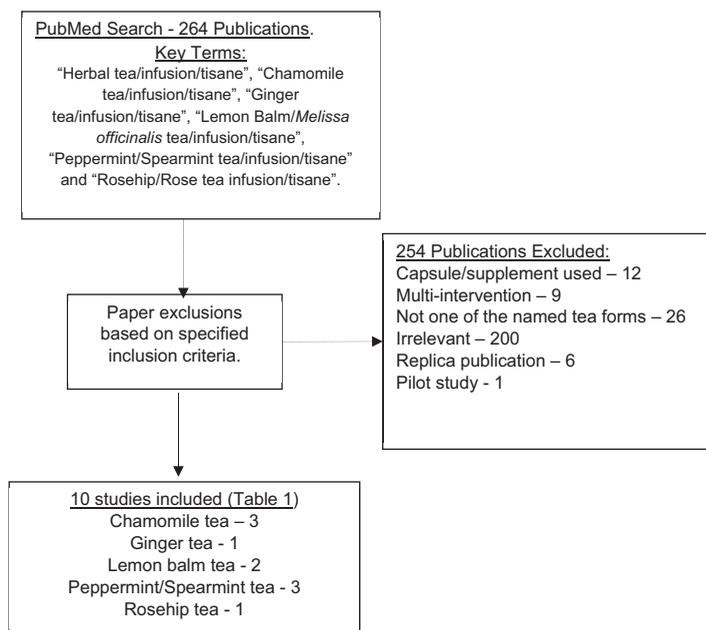


Figure 1.
Algorithm for
database search
results

disorders, rheumatic pain and haemorrhoids (Srivastava *et al.*, 2010). It is estimated that in the UK alone, over 450,000 cups of chamomile tea are drunk daily – the equivalent of over 165,000,000 cups a year (Nielsen, 2019).

Three randomised controlled trials (RCTs) studied the effects of German chamomile tea consumption on aspects of health. In these trials, participants drank either one 300 ml cup of chamomile tea (of German origin) daily (Chang and Chen, 2016) or three 150 ml cups daily immediately after meals (Zemestani *et al.*, 2016; Rafraf *et al.*, 2015). The first trial recruiting 80 women 6 weeks postpartum found that drinking just 1 cup (300 ml) of German chamomile tea (infused for up to 15 min) appeared to have a sedative-hypnotic effect improving sleep quality and symptoms of depression after 2 weeks of consumption (Chang and Chen, 2016).

Two trials focussed on the markers of glycaemic control in patients with type 2 diabetes mellitus (T2DM) (Zemestani *et al.*, 2016; Rafraf *et al.*, 2015). One found that after 8 weeks of German chamomile tea consumption thrice daily (150 ml each time) significantly reduced serum insulin, total cholesterol, triglyceride, low-density lipoprotein cholesterol and glycosylated haemoglobin (HbA1c) levels in adults with T2D at baseline versus the hot water group (Rafraf *et al.*, 2015). Another similar trial showed that total anti-oxidant capacity, superoxide dismutase, glutathione peroxidase and catalase activities increased significantly by 7 per cent, 26 per cent, 37 per cent and 45 per cent, respectively, after 8 weeks of drinking German chamomile tea (Zemestani *et al.*, 2016).

Regarding active ingredients, dried German chamomile flowers provide an array of phenolic compounds including flavonoids: apigenin, quercetin, patuletin, luteolin and their glucosides (Srivastava *et al.*, 2010) which some of their medical properties could be attributed to. Recently, German chamomile tea has been identified as a source of structurally diverse polysaccharides, including inulin, fructo-oligosaccharides and pectin, which are well-established prebiotics (Chaves *et al.*, 2019). Mechanistically, laboratory studies have

similarly shown that German chamomile has cholesterol-lowering and anxiolytic effects (McKay and Blumberg, 2006a). *In vivo* work (Villa-Rodriguez *et al.*, 2017) shows that German chamomile tea inhibits digestive enzymes related to sugar release along with sugar transport pathways (GLUT2 and GLUT5), potentially managing sugar absorption and metabolism. Together, this could explain some of the findings from the identified RCTs.

Ginger tea

Ginger (*Zingiber officinale* Roscoe Zingiberaceae) is a rhizome (root) with a long history of use in traditional medicine, which has been attributed to its constituents: 6-gingerol, 6-shogaol, 6-paradol, zingerone and dehydrozingerone (Choi *et al.*, 2018). It has been postulated that ginger could modulate obesity by increasing thermogenesis and lipolysis, suppressing lipogenesis, inhibiting intestinal fat absorption and controlling appetite (Ebrahimzadeh Attari *et al.*, 2018). Ginger is also thought to have gastroprotective effects which have been linked to its phenolic, free radical scavenging and inhibition of lipid peroxidation properties (Haniadka *et al.*, 2013).

While a growing number of studies have looked at ginger *per se* in relation to health, few trials have focussed on ginger tea. One study (Chao *et al.*, 2011) found that stroke volume increased and pulse pressure decreased in non-heat constitution subjects (neutral and partial cold body temperature) after drinking 250 ml aged ginger tea compared with baseline, indicating effects on sympathetic activity.

Most mechanistic studies refer to ginger rather than ginger tea. It is known that ginger extract and its constituent components have anti-oxidant properties that could be attributed to their hydroxyl structure (Si *et al.*, 2018). *In vitro* both [6]-shogaol and [6]-gingerol, the major active components in ginger, significantly trapped methylglyoxal (a reactive metabolite derived from glucose and lipids), which can contribute to protein glycation and the formation of advanced glycation end products. While these effects look promising, ongoing research using ginger “tea” is now needed.

Lemon balm tea

Lemon balm (*Melissa officinalis* L. Lamiaceae) is a perennial herb. It is also sometimes referred to as “bee balm”, “garden balm”, “Melissa” or “melissengeist” (Rasmussen, 2011). Lemon balm has been used both historically and contemporarily as a modulator of cognition and mood, including its anxiolytic effects (Scholey *et al.*, 2014).

Two human trials have used lemon balm tea in their intervention. In an open-label parallel trial, 28 healthy Japanese subjects drank either one 200 ml cup of lemon balm or barley tea (the control) daily for over 6 weeks. In the lemon balm group, brachial-ankle pulse wave velocity (an indicator of arterial stiffness) reduced significantly while female skin cheek elasticity improved (Yui *et al.*, 2017). A before–after clinical trial (Zeraatpishe *et al.*, 2011) provided 55 radiology staff with a lemon balm infusion twice daily (each 100 ml) for over 30 days. Consumption led to significant improvements in plasma catalase, superoxide dismutase and glutathione peroxidase, protecting against oxidative stress, while DNA damage, myeloperoxidase and lipid peroxidation were reduced (Zeraatpishe *et al.*, 2011).

These findings suggest that lemon balm infusion could have physiological benefits. Other work has shown that lemon balm *per se* possesses high amount of anti-oxidant activity through its chemical compounds potentially alleviating oxidative stress-related disease (Miraj *et al.*, 2017). Some research has found that delivering lemon balm as a water-based drink (but not tea) observed some improvements in mood and/or cognitive performance (Scholey *et al.*, 2014).

Regarding mechanisms, laboratory research shows that lemon balm extract activates peroxisome proliferator-activated receptors, which have key roles in the regulation of whole body glucose and lipid metabolism (Weidner *et al.*, 2014). In a cell model, lemon balm extract promoted melanogenesis, helping to possibly prevent UVB damage which could be linked to some of the skin elasticity effects (Perez-Sanchez *et al.*, 2016). Overall, lemon balm appears to have multi-faceted effects though the forms and dosages required to initiate these effects warrant further study.

Spearmint/peppermint tea

There are two main forms of *Mentha* drunk as infusions – *Mentha spicata* L. *Lamiaceae* (spearmint) and *Mentha x piperita* L. *Lamiaceae* (peppermint) (Akdogan *et al.*, 2007). Spearmint has traditionally been used for various kinds of illnesses in herbal medicine and flavouring in the food industry (Akdogan *et al.*, 2007). Peppermint is also one of the most popular and widely consumed herbal teas or tisanes (McKay and Blumberg, 2006b). *Mentha* leaves provide the phenolic rosmarinic acid (rosA) and flavonoids including eriocitrin, hesperidin and luteolin (McKay and Blumberg, 2006b).

Three human trials focussed on *Mentha* teas and aspects of health. Two trials examined the effects of spearmint tea on female androgen levels (Grant, 2010; Akdogan *et al.*, 2007). A 30-day RCT comprised 42 females with hirsutism found that spearmint tea consumption (2 cups daily) led to significant reductions in total and free testosterone levels, improved luteinising hormone (LH) and follicle stimulating hormone (FSH) levels and the patient's subjective assessment of hirsutism (Grant, 2010). An intervention study comprised 21 hirsute patients provided with 2 cups of spearmint tea daily had similar effects. Significant reduction in free testosterone and increase in LH, FSH and oestradiol after 5 days were observed compared with baseline (Akdogan *et al.*, 2007). These findings imply that that spearmint tea has anti-androgenic properties but longer studies are needed.

In another trial, 62 participants with medically diagnosed osteoarthritis were randomised to drink high-rosA spearmint tea or commercial spearmint tea twice daily over 16 weeks. Daily ingestion of both high-rosA and commercial spearmint teas significantly improved stiffness and physical disability scores in subjects with knee osteoarthritis, but only the high-rosA tea significantly decreased pain (Connelly *et al.*, 2014).

Mechanistically, peppermint tea has also been found to modulate hormone levels in animal research. In further laboratory studies, peppermint tea exposure also reduced total testosterone and increased FSH and LH levels (Akdogan *et al.*, 2004). In other work, high-rosA *Mentha* has been found to be an effective inhibitor of lipopolysaccharide-induced inflammation seen in cartilage explants (Pearson *et al.*, 2010). Other laboratory work suggests plausible anti-inflammatory effects (Arumugam *et al.*, 2008).

Rosehip tea

Rosehip (*Rosa canina* L. *Rosaceae*) is an abundant source of vitamin C and polyphenolic compounds – components that could prevent oxidation-related disease (Tumbas *et al.*, 2012). The wild rosehip fruit is also naturally high (12.9-35.2 mg/100g) in lycopene, the pigment found in tomatoes (Bohm *et al.*, 2003).

The use of rosehip tea to alleviate menstrual pain has long been a part of traditional folk knowledge (Tseng *et al.*, 2005). One six-month RCT, comprised 130 teenagers with primary dysmenorrhoea (menstrual cramps), found that 2 cups of rosehip tea daily (each 300 ml) consumed 1 week before and 5 days after commencing menstruation reduced perception of menstrual pain, distress and anxiety and reported greater psychophysiological well-being

compared to placebo (Tseng *et al.*, 2005). Findings suggest that rosehip tea could be an effective non-pharmacological strategy for women with primary dysmenorrhoea.

Further research now needs to study biochemical markers such as hormone levels. Mechanistic studies are lacking, but some research has investigated effects of brewing conditions. It was found that the optimal “brewing conditions” for rosehip tea was an infusion time of 6-8 min and temperature 84-86°C which resulted in the tea providing 3.15 mg 100 ml⁻¹ of ascorbic acid, 61.44 mg 100 ml⁻¹ of total phenolic content and 2,591 μmol of ferric reducing anti-oxidant power (Ilyasoglu and Arpa, 2017). These valuable findings should be embedded when designing future rosehip tea trials and their methods.

Discussion

Herbal infusions have gained popularity, particularly amongst health conscious consumers and have diffused into the common market – now being consumed alongside other popular beverages such as tea, coffee and cocoa which are also prepared using plant materials (Chandrasekara and Shahidi, 2018). The present review shows that a growing number of studies, including human RCTs, have investigated herbal infusion consumption in relation to aspects of health and wellness.

It should be appreciated that seven of the ten studies conducted were good quality (Table II). RCTs using herbal infusions as an intervention can be challenging to undertake. For example, most studies were “single” blinded and this was typically the investigator rather than the patient. Blinding herbal infusions can be difficult, as many herbal infusions have distinct flavours and sensory properties.

The health outcomes studied have been wide-ranging from improvements in glycaemic control and lipid profile (German chamomile) to aspects of women’s health (German chamomile, peppermint and rosehip tea) (Table I). Of the evidence available, the studies investigating inter-relationships between German chamomile tea consumption and glycaemic/lipid control look particularly promising (Zemestani *et al.*, 2016; Rafraf *et al.*, 2015). These RCTs were well-conducted and high quality, ranking five on the Jadad scale (Table II).

Similarly two trials focussing on spearmint tea were also ranked as being “high-quality” with 1 cup daily for reducing stiffness in patients with knee osteoarthritis (Connelly *et al.*, 2014) and 2 cups daily for improving hormone levels and symptoms of hirsutism in patients with polycystic ovary syndrome (PCOS) at baseline (Grant, 2010). There a strong body of evidence showing that PCOS can impact negatively on quality of life, with hirsutism being presented as a factor contributing to this (Aliasghari *et al.*, 2017). Given this, the drinking of spearmint tea could play an important role in supporting the management of such conditions.

Other human trials also yielded interesting findings. For example, lemon balm tea could help to prevent glycation-associated tissue damage in blood vessels and skin of healthy adults (Yui *et al.*, 2017). Based on the work by Chang *et al.* (2016), German chamomile tea could be recommended to postpartum women as a supplementary approach to alleviating depression and sleep quality problems. Similarly, rose tea could potentially benefit females with dysmenorrhoea, which can be a painful and debilitating condition affecting between 45 and 95 per cent of menstruating women (Tseng *et al.*, 2005; Iacovides *et al.*, 2015).

Elsewhere there appears to be emerging evidence for other herbal infusions too. Such benefits, by and large, may be attributed to their polyphenol and flavonoid profiles. For example, cinnamon (*Cinnamomum verum* J. Presl Lauraceae) tea reduced postprandial blood sugar levels in one trial, which was thought to be because of its polyphenol content and high anti-oxidant capacity (Bernardo *et al.*, 2015). Echinacea (*Echinacea spp.* Asteraceae)

tea – made from the leaves (not root) of two Echinacea species – in a randomised, double-blind trial was effective at relieving early onset cold and flu symptoms, though intakes were higher (5-6 cups) in this particular trial (Lindenmuth and Lindenmuth, 2000). Amongst prehypertensive and mildly hypertensive adults, hibiscus tea (*Hibiscus sabdariffa* L. *Malvaceae*) – three 240 ml cups daily over six weeks significantly reduced systolic blood pressure (McKay *et al.*, 2010).

Overall, a growing number of trials are being conducted to investigate herbals teas and health. Interestingly, interest in organic teas also appears to be gaining momentum. A survey of 202 Chinese shoppers revealed that consumers perceiving organic tea as a healthy option and as a status symbol were more likely to report organic tea purchase intentions (James *et al.*, 2019). Synergistic combinations of herbal teas could also confer health benefits. For example in one study, a mixture of two South African indigenous herbal teas (bush tea – *Athrixia phylicoides* DC and special tea – *Monsonia burkeana* Planch. *ex Harv*) were reported to have high anti-oxidant activities that could play a role in the management of health conditions such as diabetes (Mathivha *et al.*, 2019). Given the array and combinations of herbal infusions available, the evidence will take time to build.

In the meantime, herbal teas appear to be a valuable source of phytochemicals, such as flavonoids and other polyphenols, in the human diet. Generally, their consumption also tends to be without additional sugar or milk. As such, herbal tea consumption is a useful way to obtain anti-oxidants and bio-actives without providing surplus energy or sugar. Presently in the UK, herbal infusions are not mentioned specifically in the Eatwell Guide. This states that the public should: “Aim to drink 6-8 glasses of fluid every day. Water, lower fat milk and sugar-free drinks including tea and coffee all count” (PHE, 2018). There is scope, as evidence accumulates, to further embed herbal infusions within such guidelines.

Future research

Regarding future research, multiple daily consumptions may be needed to generate further effects. In the present studies, benefits were observed at fairly low levels of herbal infusion consumption (1-3 cups daily). Higher intakes could lead to more detectable changes in markers of health. It should be considered, however, that better standardisation is needed in terms of what constitutes “a cup”, as this ranged in size from 100 to 300 ml. It has been mentioned previously that interventions should be well characterised to aid uniformity and enable a common body of evidence to be developed (Dwyer and Peterson, 2013).

Tea forms should also be used that can be more generalisable to daily life. For example, a recent quality assessment of marketed chamomile tea found that it was crude flowers that were most likely to be adulterated by other plant materials compared to German chamomile tea bags (Guzelmeric *et al.*, 2017). Bearing this in mind, baseline biochemical analysis of the tea interventions would be worthy before progressing on to trials. Following on from this, modes of tea preparation – including weight of herbal product – the volume of water added and infusion times should be kept as consistent as possible.

Self-reported assessments of health and well-being can be somewhat subjective, so ongoing biomarkers of health are needed in future work. Mechanistic studies should continue to determine which tea bioactive constituents generate health effects and whether these act alone or in combination (Dwyer and Peterson, 2013). These should also be conducted using the tea *per se*, as most have focussed on the herb or plant itself rather than tea in beverage form.

Being in the era of anti-biotic resistance, there is great potential to further study the anti-microbial properties and activities of herbal teas. A recent *in vitro* study found that rosehip, mint, Echinacea tea bags, cinnamon, black and green teas, amongst others were active

against most of the studied microorganisms (Hacıoglu *et al.*, 2017). Interestingly, however, rosehip (and pomegranate blossom) were antagonistic with some anti-biotics indicating that they would be better consumed alone for their anti-microbial activities and avoided when on a course of anti-biotics (Hacıoglu *et al.*, 2017).

Conclusion

There is growing interest in whether herbal infusions could contribute to healthy living and preventative health. Our review collating evidence from human trials demonstrated that drinking 1-3 cups daily of certain herbal infusions could confer health benefits. In particular, German chamomile tea appears to improve anti-oxidant status and glycaemic/lipid profiles. German chamomile, spearmint and rose teas could also benefit aspects of women health including sleep quality, hormonal control and primary dysmenorrhea. Evidence for ginger and lemon balm also look promising but ongoing human trials are needed.

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