



Turmeric

An Overview of Potential Health Benefits

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The spice turmeric, derived from the rhizome of *Curcuma longa* L, has been used for centuries in food preparation and in traditional medicines to treat numerous diseases and conditions. The primary biologically active constituent of turmeric is the polyphenol, curcumin, an orange-yellow powder that has potent anti-inflammatory and antioxidant properties, which, in part, may contribute to curcumin's potential to prevent such conditions as cancer, Alzheimer disease, heart disease, and arthritis, to name a few. Clinical confirmation of these putative benefits is limited, however, and progress in establishing the in vivo efficacy in humans especially at typical dietary intakes is constrained by the poor bioavailability of this hydrophobic molecule. Strategies to improve absorption and distribution of curcumin in foods and findings from ongoing clinical studies should improve our understanding of how curcumin can best be used to improve human health. *Nutr Today*. 2010;45(5):216–225

The rhizome of the turmeric plant, *Curcuma longa* L (Zingiberaceae family), has been used for centuries as a spice in the Middle East and Asia as well as a traditional medicine for a variety of diseases.¹ It even has been found its recent use for improving dental health.² It is used as an ingredient in perfumes, as a natural yellow coloring agent, and as an approved food additive.¹ In contrast to their use in traditional medicines, natural products used in the context of Western medical uses must demonstrate efficacy based on biomedical research in which experimental results are testable and reproducible. Health benefits should be based on scientifically supported explanations of improvements in pathology. This overview is an attempt to highlight such evidence pertaining to turmeric.

Turmeric is widely consumed especially in the Indian subcontinent and contains, as one of its most active constituents, the polyphenol curcumin (diferuloylmethane). Curcumin is often ingested as a component of curry, although curry generally contains a small amount of curcumin, and its content can vary considerably.³ Curcumin, an orange-yellow crystalline powder, has been reported to possess potential health benefits for numerous inflammatory diseases (such as arthritis and cardiovascular disease), as well as for cancer and diabetes.^{4,5} It is not surprising that there is high interest in curcumin as a lead molecule in anti-inflammatory drug development strategies.⁶ Likewise, other curcuminoids, for example, those lacking 1 or both methoxy groups (demethoxycurcumin and bisdemethoxycurcumin), have biological activity. Curcumin can affect molecular targets to improve health via a variety of mechanisms. For example, curcumin can affect the expression and activity of a variety of enzymes, such as cyclooxygenase, lipoxygenase, glutathione- S-transferase, and cytochrome P450. It has been reported to modulate transcription factors, growth factors, growth factor receptors, and their associated signaling pathways, such as epidermal growth factor receptor, fibroblast growth factor 2, AP-1, nuclear factor κB, and Nrf2. Curcumin can affect cytokine expression and activity (eg, IL-6, tumor necrosis factor, IL-8) and can alter cell proliferation, in part by influencing cyclin protein actions. Furthermore, it has antioxidant properties. The effects of curcumin on transcription factor-associated signaling and cytokine actions contribute to its anti-inflammatory actions. Its antiproliferative effects, its influence on oncogene and tumor suppressor gene signaling, and its modulation of biotransformation enzymes contribute to its anticancer actions. These multiple biological actions of curcumin likely account for the wide range of benefits reported toward arthritis, neurological conditions, diabetes, and other diseases.

Based on its historical use in Asian populations and on the results from preclinical and clinical studies, there are no serious toxicity concerns associated with usual consumption of turmeric or curcumin. Human trials



"Turmeric"
Curcuma longa

Curcuma longa plant. Obtained from McCormick & Company, Inc.

indicate that intakes as high as 8 g curcumin per day are well tolerated, and an intake of 12 g/d has been reported to have no adverse consequences.⁷⁻¹⁴ This relatively low toxicity may in part be due to curcumin's poor solubility in water and its rapid degradation in the gastrointestinal (GI) tract, which consequently limit its bioavailability^{7,15,16} and impair the practical use of this phytochemical in prevention and therapeutic strategies. For example, 8-g/d intake of curcumin by humans results in a maximum serum concentration of only about 1.7 μM .¹ The reasons for this low bioavailability are several. First of all, the hydrophobic curcumin molecule exhibits limited absorption from the gut. Furthermore, that portion of an oral dose that is absorbed undergoes extensive reduction and subsequent metabolism to glucuronide and sulfate conjugates, processes occurring predominantly in the GI tract and liver.⁷ Genetic variability in curcumin metabolism is suspected but has not been well characterized.¹ The bioactivities of the metabolites and conjugates of curcumin are not fully understood. Ultimately, curcumin is rapidly eliminated and excreted in large amounts from the gut.⁷ This issue underscores the need to consider the physiological relevance of the doses of curcumin or turmeric administered in the studies highlighted in this overview. Human oral intakes of curcumin in amounts greater than 8 g appear impractical and unlikely to be applicable to culinary or usual dietary uses. Even at this level of intake, circulating concentrations of curcumin are likely to be

less than 5 μM , which raises concerns about the physiological relevance of many in vitro experiments. In light of the fact that curcumin has multiple biological actions and possesses considerable potential as a preventive and therapeutic agent for numerous conditions, a number of strategies are being tested to improve its bioavailability and efficacy to enhance targeted drug delivery.^{7,17,18} These include providing curcumin as a liposomal, micellar, or nanoparticle preparation or delivering it within a phospholipid complex.¹⁹ Structural analogs of curcumin have been evaluated for their improved absorption and distribution, and administration of curcumin along with an adjuvant such as the phytochemical piperine (20 mg/kg body weight in rats or 20 mg in humans), an inhibitor of glucuronidation, has been evaluated as a means to lower curcumin's rapid metabolism and elimination from the gut.^{7,11,20} It should be pointed out, however, that limiting bioavailability may be the body's way to address potential toxicity. Similarly, substantially enhancing curcumin bioavailability might also increase unwanted adverse effects. This must be carefully evaluated in future investigations.

Over the last quarter century, curcumin has been extensively evaluated for its health-promoting properties. A large body of preclinical investigations provides substantial and compelling support for curcumin's antioxidant, immunomodulatory, and anti-inflammatory properties that collectively contribute to its capacity to potentially alleviate multiple disease conditions.²¹⁻²³ Clinical studies are less numerous but are growing in number.^{1,4,12,24}

A summary of several biological actions of turmeric or curcumin is presented in the Table, and an effort is made to give an overview of the variety of scientific research on this topic. Points of view for rating of evidence in each category are based on consideration of the number and quality of cell culture experiments, animal studies, and human clinical data from the peer-reviewed scientific literature. Justification for a higher rating depended on the presence of both preclinical and clinical data, in vivo data from relevant and well-controlled animal models, and consistency of findings among well-controlled human studies.

Safety

Turmeric is an approved food additive for humans. Several animal studies conducted in a wide variety of models confirmed a lack of significant toxicity. Doses of curcumin administered in some studies were as high as 3.5 to 5.0g/kg body weight or as high as 50 000-ppm turmeric oleoresin in the diet and lasted several months in duration.^{13,109-112} Likewise, clinical data indicate that curcumin elicited no significant adverse effects at oral

Table. Potential Health Benefits of Turmeric and Curcumin

Potential Health Benefit	Rating ^a
<p>Anticancer actions</p> <p><i>Clinical evidence</i></p> <p>Curcumin has been evaluated in several clinical studies for its action toward precancer lesions and surrogate tumor biomarkers.^{10,20,25} For example, patients with advanced colorectal cancer consuming 3.6 g curcumin per day for 4 mo evidenced in leukocytes a reduction in inducible prostaglandin E₂ levels, an indicator of cyclooxygenase (COX) 2 activity.²⁵ Likewise, levels of the deoxyguanosine M1G adduct, an indicator of oxidative DNA damage, were decreased in malignant colorectal tissue of individuals consuming 3.6 g curcumin for 1 wk. However, the opposite response to curcumin was observed in normal liver tissue and colorectal liver metastases.²⁵ In a small pilot study, curcumin (1440 mg/d along with 60 mg quercetin) lowered the number and size of polyps in patients with familial adenomatous polyposis.²⁶ Recently, results of a phase 2 study of the chemotherapeutic drug gemcitabine in combination with curcumin (8 g/d) for up to 12 mo duration were reported. The preliminary findings point to this combination strategy for treatment of advanced pancreatic cancer as worthy of further study, although some abdominal distress in a subset of patients was encountered.^{27,28} Additional clinical cancer trials are in progress targeting numerous tissue neoplasms.^{24,29}</p>	P
<p><i>Preclinical evidence</i></p> <p>Preclinical experiments indicate that administration of curcumin or turmeric can suppress several stages of cancer development in multiple tumor models.^{15,21,30–35} Modified delivery strategies (eg, pegylation of curcumin or incorporation into nanoemulsions) and novel structural analogs of curcumin have been shown to enhance its efficacy.^{36–38} In contrast, there is a study using a transgenic mouse model of lung cancer expressing human Ki-ras in a lung-specific manner, in which dietary curcumin (4000 ppm) increased oxidative stress and lung tumorigenesis.³⁹ The authors warned that curcumin may exhibit lung-specific capacity to accelerate reactive oxygen species formation and damage lung tissue of smokers and ex-smokers. Other toxic and carcinogenic properties of curcumin have been described.³¹ The mechanisms underlying curcumin's anticancer actions include inhibiting carcinogen metabolism; suppressing tumor invasion and metastasis; disrupting regulation of transcription factors, growth factors, protein kinases, or mTOR; and modulating levels of inflammatory cytokines that control cell proliferation, angiogenesis, and apoptosis.^{4,5,29,30,40–43} In this regard, 2 reports of in vitro studies indicate that curcumin may induce degradation of the tumor suppressor protein p53 and inhibit its activity,^{44,45} results that raise concerns about safety, although these findings have not been confirmed in vivo. Of relevance to cancer treatment, administration of curcumin to mice (100–250 mg/kg) has been reported to have potential use in adjuvant therapy of proteolysis and muscle wasting accompanying cachexia and other catabolic conditions.^{46,47}</p>	
<p>Alleviation of gastrointestinal tract disorders</p> <p><i>Clinical evidence</i></p> <p>There is clinical evidence that oral curcumin may help alleviate common symptoms of irritable bowel disease as well as those of patients with ulcerative colitis.^{20,23,24,29,48–50} For example, curcumin improved clinical indices of disease, Crohn Disease Activity Index, and endoscopic indices. Doses of curcumin used in these studies ranged from 0.5 to 12 g/d over periods of 1 d to 6 mo.</p> <p><i>Preclinical evidence</i></p> <p>Preclinical studies have provided additional evidence that curcumin can suppress experimental colitis and intestinal inflammation. This anti-inflammatory action was mediated in part by diverse mechanisms including suppression of nuclear factor κB (NF-κB) activation, proinflammatory cytokine expression, and generation of reactive nitrogen and oxygen species in colonic mucosa or inflammatory cells.^{4,23,24,51} Colonic delivery of solid lipid microparticles of curcumin in a rat colitis model substantially attenuated colonic inflammation.⁵² Collectively, these results clearly support the need for larger, well-controlled clinical studies.</p>	P

Table. Potential Health Benefits of Turmeric and Curcumin, continued

Potential Health Benefit	Rating ^a
<p>Diabetes and metabolic syndrome</p> <p><i>Preclinical evidence</i></p> <p>There are several reports using experimental rodent models suggesting that curcumin administration (80 mg/kg, i.g., for 21 d) can alleviate hyperglycemia and other consequences of diabetes.^{4,23} Besides decreasing blood glucose levels, curcumin has been observed in animals to increase plasma insulin levels, inhibit diabetic cataracts, counteract dyslipidemia and renal dysfunction, and attenuate diabetes-associated neuropathic pain.^{4,23,53} Supplementing a high-fat diet of mice with curcumin (500-mg/kg diet) for 12 wk reduced body weight gain, adiposity, and microvessel density in adipose tissue, changes that coincided with decreased serum cholesterol, increased fatty acid oxidation, and decreased fatty acid esterification, compared with controls.⁵⁴ The mechanisms mediating these multiple effects in rodents are several. Curcumin may suppress inflammatory processes mediated by cytokines (eg, tumor necrosis factor) and transcription factors (such as NF-κB, and peroxisome proliferator-activated receptor γ [PPAR-γ]) as well as inhibit oxidative stress, suppress peroxidation, and scavenge free radicals.^{4,23,26} Curcumin also has been shown to inhibit protein glycosylation. Curcumin's actions in inhibiting adipogenesis and lipogenesis may be mediated by its inhibition of expression of the transcription factors PPAR-γ and CCAAT/enhancer-binding protein and its suppression of vascular endothelial growth factor and vascular endothelial growth factor receptor 2 expression.⁵⁴ It has been reported also in an in vitro study that curcumin (40 μM) may enhance the survival of β cells of human pancreatic islets and thus may potentially improve islet transplantation outcomes.⁵⁵</p> <p><i>Clinical evidence</i></p> <p>In contrast to animal models and preclinical investigations, there is limited human evidence demonstrating similar efficacy of curcumin. An early study⁵⁶ reported that curcumin can alter blood glucose levels in a diabetic patient. More recently, a preparation of curcuminoids favorably affected blood levels of inflammatory stress biomarkers in patients with type 2 diabetes. This was accompanied by improvement in endothelial dysfunction.⁵⁷</p>	P
<p>Cardioprotective properties</p> <p><i>Preclinical evidence</i></p> <p>There is considerable preclinical evidence indicating that curcumin exhibits a variety of cardioprotective properties. First of all, curcumin may protect against cardiac injury, in large part because of its anti-inflammatory actions. Several animal studies have suggested that curcumin administration (eg, 70–100 μmol/kg, intravenously) protects the heart from damage following cardiac ischemia and reperfusion (I/R) and from cardiopulmonary bypass (CPB).^{23,58,59} Curcumin acted in part to protect the myocardium against ischemic damage by suppressing pathways generating reactive oxygen species and lipid peroxidation and by upregulating other pathways that detoxify free radicals. I/R and CPB were ameliorated by curcumin's ability to counteract the upregulation of cardiac proinflammatory genes and to suppress the production of proinflammatory cytokines following damage to the heart.^{23,58} In mice, curcumin dosing (50–100 mg/kg per day, subcutaneously, for 1–2 wk) prevented experimentally induced cardiac hypertrophy, fibrosis, inflammation, and heart failure in part via its inhibition of p300 histone acetyltransferase.¹⁹ Curcumin also inhibited chemically induced cardiac injury following administration of such agents as isoproterenol and adriamycin.^{58,60}</p> <p>Curcumin may be cardioprotective by suppressing atherosclerotic lesion development. It can act in a variety of ways to do so, including inhibiting low-density lipoprotein oxidation, suppressing proliferation of vascular smooth muscle cells, decreasing thrombosis, reducing aortic fatty streak formation, and blocking homocysteine-induced endothelial dysfunction.^{23,26,58,60,61} Provision of curcuminoids (30–90 mg/kg per day, i.g., for 12 wk) also has a lipid-lowering effect in rats fed high-fat diet.⁶² There is some speculation that curcumin's anti-inflammatory actions may help in the prevention of atrial and ventricular arrhythmias.⁶⁰ Recent preliminary evidence suggests that curcumin has the potential to prevent stroke and lessen vascular inflammation and cerebral vasospasm following hemorrhagic stroke.^{63–65} Again, these beneficial cardiovascular effects of curcumin are apparently a consequence of its multiple antioxidant and anti-inflammatory actions.^{4,26,61} In contrast, there is one preclinical study in which curcumin exhibited deleterious effects toward heart tissue exposed to chronic hypoxia by inactivating p53, p38, and C-Jun kinase pathways.²⁶</p>	P

(continues)

Table. Potential Health Benefits of Turmeric and Curcumin, continued

Potential Health Benefit	Rating ^a
<p><i>Clinical evidence</i> Well-controlled clinical trials in humans that examine curcumin's efficacy toward cardiovascular disease and its biomarkers are relatively few in number.¹² Clearly, additional clinical trials are warranted to confirm these animal and cell culture data.</p>	
<p>Benefits for neurodegenerative disorders and cognition</p> <p><i>Preclinical evidence</i> There is experimental evidence that curcumin may lessen the development and progression of Alzheimer disease (AD). In vitro studies indicate that curcumin exhibits anti-inflammatory properties that could counteract neurodegeneration.^{23,26,66,67} Curcumin also has been reported to block β-amyloid aggregation and fibril formation as well as to stimulate β-amyloid removal by mononuclear cells of AD patients.^{23,66,68} In animal models of AD, dietary curcumin (160–5000 ppm) has been observed to suppress levels of β-amyloid and plaque burden and other concomitant pathologies.^{23,26,66} For example, in an in vivo study, curcumin injected into the blood (7.5 mg/kg per day, 7 d) disrupted existing amyloid plaques and partially reversed neurite distortions in an AD mouse model.⁶⁹ In a variety of animal models of AD, dementia, and aging, curcumin also has been noted to improve memory function and cognition.^{66,70–76} Curcumin's capacity to lower serum cholesterol and lipid peroxides as well as to inhibit platelet aggregation may additionally improve symptoms of dementia.⁶⁶ Of related interest, curcumin is reported to be effective in counteracting oxidative stress and impaired cognition associated with traumatic brain injury.^{77,78}</p> <p><i>Human evidence</i> There are few human studies examining curcumin as an agent to ameliorate neurological disorders. An epidemiological study of elderly Singaporeans who ate curry with turmeric had better cognitive function than those not consuming curry.⁷⁹ A recently published 6-mo randomized, placebo-controlled, double-blind clinical trial reported, however, that AD patients who consumed 4 g curcumin per day exhibited no protective effect.⁸⁰ The authors attributed this lack of benefit in part to insufficient cognitive decline in the placebo group during the relatively short 6-mo period of this intervention. Of interest, however, was that an increase in serum β-amyloid 40 in curcumin-treated patients was observed, which possibly reflects curcumin-induced disaggregation of β-amyloid deposits in the brain.^{23,80} Data from additional clinical studies should be forthcoming.^{4,23,66}</p>	P
<p>Alleviation of arthritic diseases</p> <p><i>Preclinical evidence</i> Curcumin's potent anti-inflammatory properties have prompted examination of its potential for preventing and managing rheumatoid arthritis and other related conditions.⁸¹ There is preclinical evidence that curcumin has the potential to improve arthritis symptoms. Administration of curcumin to rodents (eg, 4 mg/kg per day, intraperitoneally [IP]) using experimental models of arthritis resulted in reduced levels of tissue inflammation as well as decreased expression of inflammation-associated cytokines and other inflammatory mediators.^{23,82} Notably, curcumin can decrease expression of COX-2 and, in combination with celecoxib, can synergistically inhibit the COX-2 activity and cell proliferation associated with osteoarthritis. Other natural products, such as the isothiocyanate sulforaphane, may synergize with curcumin in suppressing inflammation.⁸³ A randomized, double-blind, placebo-controlled study of the effect of a mixture of curcuminoids on canine osteoarthritis yielded mixed results, however.⁸⁴</p> <p><i>Clinical evidence</i> There is limited clinical evidence supporting the antirheumatic actions of curcumin,^{4,23,24,85,86} prompting the recommendation that turmeric should not be used to treat osteoarthritis until reliable clinical evidence is provided.⁸⁵ Studies are in progress evaluating the efficacy of curcumin and celecoxib in treating patients with osteoarthritic disease.⁸⁷</p>	P
<p>Allergy Data from several animal studies suggest that curcumin can ameliorate immune cell-associated bronchial inflammation.^{88,89}</p>	P

Table. Potential Health Benefits of Turmeric and Curcumin, continued

Potential Health Benefit	Rating ^a
<p>Actions against infections and parasitic diseases.</p> <p>There are very limited evidence and mixed results regarding curcumin's efficacy in counteracting microbial and viral infections. It was ineffective in reducing viral loads or CD4 counts in patients with HIV, although it did resolve HIV-associated diarrhea.^{12,90} Curcuminoids did show potential as antitubercular agents.⁹¹ A recent report suggests that curcumin demonstrated antibacterial activity toward human clinical isolates of <i>Helicobacter pylori</i> and substantially reduced <i>H pylori</i>-induced gastric damage in infected mice.⁹² Curcumin also has been reported recently to possess antimalarial and antiparasitic properties.⁹³⁻⁹⁶ In one mouse study, for example, curcumin given IP (400 mg/kg per day) to <i>Schistosoma mansoni</i>-infected mice altered cellular and humoral immune responses that coincided with a decrease in parasitic burden and liver pathology.⁹³</p> <p>Miscellaneous effects</p> <p>There are preliminary data suggesting that curcumin may be beneficial in the prevention or treatment of other diverse conditions. Topical use of curcumin has been noted to improve outcomes in patients with psoriasis,¹² and its use as a nontoxic agent for treating a variety of skin disorders has been advocated.^{23,24,97,98} Curcuminoids have been recommended as a cosmeceutical ingredient for dermatologic applications.⁹⁹ Curcumin has been shown to ameliorate renal failure in rats, to protect the kidney from nonimmune injury and, as part of a bioflavonoid formulation, to improve early outcomes in cadaveric renal transplantation.¹⁰⁰⁻¹⁰² Curcumin was reported to arrest surgically developed endometriosis in mice¹⁰³ and to alleviate pathological symptoms of a mouse model of multiple sclerosis.¹⁰⁴ It also may prevent gallstone formation and a rare inflammatory disease called chronic anterior uveitis.²⁴ There is interest in curcumin for preventing loss of muscle mass and for enhancing muscle regeneration after trauma, as well as for stimulating wound healing.^{46,47,105,106} A preliminary study in rats suggested that curcumin can protect against drug-induced orofacial dyskinesia and associated brain abnormalities.¹⁰⁷ Curcumin has been reported in animal models to attenuate chronic fatigue syndrome.¹⁰⁸ In large part, these actions are associated with curcumin's ability to alter physiological processes involved in inflammation, oxidative damage, immunomodulation, and cell proliferation.^{4,6,23,24,26,82}</p>	P

^aRatings: P = preliminary, inconclusive; i.g. = intragastrically; E = emerging, suggestive; S = strong, convincing.

doses of up to 8 g/d for several months.^{1,42,113-115} Minor GI events reported include diarrhea and temporary nausea.¹⁰⁹ There is one recent report that consumption of supplemental doses of turmeric for 4 weeks resulted in a significant elevation of urinary oxalate levels and likely increased risk of kidney stone development in susceptible individuals.¹¹⁶ Curcumin consumed (300mg/d) for 6 days also was reported to reduce the bioavailability of talinolol, a drug used in the treatment of hypertension and coronary heart failure.¹¹⁷ In mice, curcumin attenuated cyclophosphamide-induced breast tumor regression and in cell culture studies has shown to have adverse effects on DNA.¹ Thus, possible curcumin-drug interactions should not be overlooked. It should be emphasized that as curcumin analogs are identified with substantially enhanced bioavailability, these issues of safety and toxicity will need to be more fully revisited.

Summary

An abundance of preclinical data point to the considerable potential of curcumin and turmeric to

contribute to the alleviation of numerous conditions, especially those mediated by dysregulated inflammation and generation of oxidative stress, such as cancer, cardiovascular disease, GI inflammatory diseases, arthritis, and Alzheimer disease. However, more detailed mechanistic characterization of curcumin's impact in the initiation and progression of these disease conditions is much needed. In regard to cancer, the preclinical studies point out that curcumin can have diverse effects on multiple processes leading to cellular transformation and tumorigenesis. However, the impact of curcumin on carcinogenesis in tissues may vary substantially, possibly depending on the experimental cancer models used. With regard to diabetes, the preclinical findings point to a number of ways that curcumin may potentially counteract the consequences of diabetes. However, more detailed molecular insights into curcumin's impact on insulin sensitivity and energy metabolism could provide more substantial justification for focused human investigations. Relative to its purported cardiovascular benefits, it would be helpful to obtain consistent evidence linking curcumin's antioxidant and anti-inflammatory

action to several well-established contributors to cardiovascular disease, such as vascular integrity, blood pressure regulation and blood clotting dynamics. Additionally, curcumin's suppression of inflammation processes and oxidative stress may provide a general explanation of its potential to prevent arthritic symptoms. However, linking these actions to counteracting specific events in the initiation and progression of arthritic pathology in sound preclinical models would yield valuable insights to be used in the design of targeted clinical studies. Overall, confirmation of these benefits in humans based on well-conducted, larger clinical trials is limited, although ongoing clinical studies should provide insights in the future. Several issues addressed in future studies could accelerate the promise of curcumin's health benefits in becoming a reality. First of all, improving the bioavailability of curcumin through development of new analogs and formulations or novel routes of administration would remove a major impediment to its widespread application and practical use.¹⁷ In light of the fact that the preponderance of evidence for curcumin's benefits is derived from cell culture and animal studies and from small, human pilot studies, there is clearly a need for larger clinical trials to provide confirmation of curcumin's potential. Such human trials should examine multiple doses and dosing schedules of well-characterized curcumin preparations, be well controlled, explore the existence of any genetic modifiers of curcumin metabolism, and document more systematically any potential toxicities that could be relevant to healthy populations.^{1,14,19,109,118,119} This information is important, because the health benefits from current culinary use of turmeric/curcumin is likely to be modest. Clarification of curcumin's disease prevention benefits based on a larger body of clinical evidence could justify dietary strategies to substantially augment its intake.

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