Selected herbals and human exercise performance[1–3]

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ABSTRACT Herbs have been used throughout history to enhance physical performance, but scientific scrutiny with controlled clinical trials has only recently been used to study such effects. The following herbs are currently used to enhance physical performance regardless of scientific evidence of effect: Chinese, Korean, and American ginsengs; Siberian ginseng, mahuang or Chinese ephedra; ashwagandha; rhodiola; yohimbe; *Cordyceps* fungus, shilajit or mummio; smilax; wild oats; Muira puama; suma (ecdysterone); *Tribulus terrestris*; saw palmetto berries; β-sitosterol and other related sterols; and wild yams (diosgenin). Controlled studies of Asian ginsengs found improvements in exercise performance when most of the following conditions were true: use of standardized root extracts, study duration (>8 wk, daily dose >1 g dried root or equivalent, large number of subjects, and older subjects. Improvements in muscular strength, maximal oxygen uptake, work capacity, fuel homeostasis, serum lactate, heart rate, visual and auditory reaction times, alertness, and psychomotor skills have also been repeatedly documented. Siberian ginseng has shown mixed results. Mahuang, ephedrine, and related alkaloids have not benefited physical performance except when combined with caffeine. Other herbs remain virtually untested. Future research on ergogenic effects of herbs should consider identity and amount of substance or presumed active ingredients administered, dose response, duration of test period, proper experimental controls, measurement of psychological and physiologic parameters (including antioxidant actions), and measurements of performance pertinent to intended uses. *Am J Clin Nutr* 2000;72(suppl):624S–36S.

KEY WORDS Herbs, dietary supplements, exercise, physical performance, ginseng, ephedra, ergogenic aids, antioxidants

INTRODUCTION

This review explores the scientific evidence for use of herbs and herbal extracts as ergogenic aids for humans who exercise. For the purposes of this review, herbs are defined as plants or plant extracts ingested for other than caloric or culinary benefit. Despite their long tradition of use by physically active persons, herbs have seldom been studied scientifically as a possible aid to physical performance. This review will stop short of considering the effects of purified or synthesized compounds found in plant foods and classified as essential nutrients, such as β-carotene, tocopherol, and ascorbate. This review will also not consider one of the most popular herbal extracts, caffeine, which has been studied extensively as an ergogenic aid, usually as the pure compound added to decaffeinated coffee so that doses are controlled. Caffeine has consistently shown ergogenic effects for both endurance and short-term exercise, as indicated by several reviews (1–4). Noncoffee herbal sources of caffeine commonly found in dietary supplement products include guarana (*Paullinia cupana*), kola nut (*Cola acuminata*), green tea (*Camilla sinensis*), and maté (*Ilex paraguayensis*). Only ginseng preparations and ephedrine alkaloids have also been studied repeatedly for their effects on human physical performance.

This review will consider such common physiologic measures of exercise performance as oxygen utilization, fuel homeostasis, and lactate accumulation as well as several other measures of interest. Psychological, psychomotor, and antioxidant effects of herbs will be presented when available. Brief descriptions of proposed mechanisms of action may require citation of animal studies.

Humans consume herbs to enhance their long-term endurance performance (eg, in running, cycling, rowing, swimming, walking, dancing, aerobics, cross-country skiing, and mountain climbing), to induce muscular hypertrophy and strength (eg, for bodybuilding, weight lifting, wrestling, strength sports, and track and field events), or to enhance performance in sport events, both skill sports and those that are recreational. Tradition, identity of ingredients, advertisements, personal endorsements, use by other athletes, and the desire to succeed represent the extent of validation for most herbs used for physical performance.

REGULATORY STATUS OF HERBS

Currently in the United States, herbs can be defined as drugs, foods, or dietary supplements. The Dietary Supplement Health Education Act (DSHEA) of 1994 [the final version of which was published in 1997 (5)], which amended the Food, Drug and Cosmetic Act of 1938, defines dietary supplements as certain foods intended to supplement the diet that are not represented as conventional foods. Herbs or other botanicals and their extracts or concentrates are specifically mentioned as dietary supplements. To be subject to DSHEA regulations the statement "dietary sup-

[1] From Weider Nutrition International, Salt Lake City.

[2] Presented at the workshop Role of Dietary Supplements for Physically Active People, held in Bethesda, MD, June 3–4, 1996.

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Am J Clin Nutr 2000;72(suppl):624S–36S. Printed in USA.

plement" must appear on the principal display panel. DSHEA allows claims of structure or function to be made for dietary supplement products but not foods. Claims are based on the manufacturer's interpretation of the scientific literature and are limited to effects of ingredients on the body's structure or function or on a person's health or well-being. A disclaimer that the Food and Drug Administration has not evaluated claims must be present on dietary supplement labels that make structure or function claims. Product distributors are required to keep substantiation on hand derived from reliable and competent scientific research, usually reported in peer-reviewed articles and texts, for any claims on file. Although herbs can be conventional foods or drugs, all of the herbs described in this review are available as dietary supplements in the United States.

Distributors of herbal products are also under the jurisdiction of the Federal Trade Commission (FTC), which monitors advertising for truthful statements that do not mislead. FTC guidelines for substantiation differ from DSHEA guidelines, a fact that may produce confusion as new regulations are enforced. It is hoped that distributors of herbal dietary supplements will disclose factual information based on peer-reviewed scientific literature, as the DSHEA intended.

Other countries classify herbs as foods, drugs, or both. In Germany, some herbs are prescription drugs that have passed stringent safety and efficacy requirements, but these drugs (herbs) are also available without a prescription. Herbal medicines are described in the German Commission E Monographs, recently translated into English by the American Botanical Council (6). Herbal drug products to treat cerebrovascular deficiency that are made from *Ginkgo biloba* leaf extracts are one of the most frequently prescribed drugs in Germany, with > 5.4 million prescriptions written in 1988 as well as over-the-counter sales (6, 7).

HERBS AS ERGOGENIC AIDS

The herbs used most commonly at present to enhance physical performance and reasons for their use by consumers are shown in **Table 1**. Some herbs are classified as adaptogens, ie, they assist normalization of body system functions altered by stress rather than exerting a stimulatory effect (7). Persons who exercise often use adaptogens because exercise is considered a form of stress. Various combinations of traditional Chinese herbs, traditional Indian (Ayurvedic) herbs, or combinations of herbs listed in Table 1 are available in the marketplace and targeted toward physical performance, but they are not considered in this paper because of a lack of scientific substantiation and because their use is uncommon.

Herbs are used to improve performance (both endurance and strength), improve recovery, maintain health during intense periods of exercise, build muscle mass, and reduce body fat (Table 1). Because of the paucity of research in this area, studies from obscure sources will be among those included in this review.

Ginseng

The most-studied herb for human physical performance is ginseng, which includes several species in the Araliaceae family and is prepared by various methods. The term *ginseng* usually refers to the species *Panax ginseng*, known as Chinese ginseng or Korean ginseng. The use of ginseng is a dietary and medicinal custom in many Asian countries, especially China and Korea. Ginseng is available in many forms: whole root, root powder (white ginseng), steamed root powder (red ginseng), teas, tinctures, and standardized root extracts containing known and reproducible amounts of ginsenosides in every batch (9). *Panax quinquefolium* (American ginseng) is more popular in China than the United States. Siberian ginseng (*Eleutherococcus senticosus*) will be considered separately in this paper.

Other plants similar to ginseng by taxonomy or traditional use include tienqi ginseng (*Panax notoginseng* or *Panax pseudoginseng*), zhu je or Japanese ginseng (*Panax japonica*), false ginseng (*Codonopsis pilosula*), prince's ginseng (*Pseudostellaria heterophylla*), dong quai (*Angelica sinensis*), and glehnia root (*Glehnia littoralis*) (9–12). Only *P. ginseng* preparations have been studied in human clinical trials of physical performance.

Chinese ginseng (P. ginseng)

Ginseng roots contain ≥13 positively identified, glycosylated steroidal saponins (ginsenosides) as likely active agents (12–16). Roots are harvested after ≥5 y of growth and contain ≈1–2% ginsenosides. Standardized extracts (exemplified by G115; GPL Ginsana Products, Lugano, Switzerland) contain ≈4% ginsenosides. Traditional use of ginseng is 3–9 g/d of powdered root, almost always combined with other herbs (12). This dose range should be borne in mind in evaluations of human studies performed in the United States.

Many mechanisms of action have been proposed for ginseng. The traditional use is to restore *Qi*, or life energy, but ginseng preparations are used for many specific purposes (6, 9–14, 17). The herb is thought to be a tonic to increase vitality, health, and longevity, especially in older persons. Isolation of ginsenosides and administration to animals has revealed activities that stimulate the central nervous system as well as those that depress it (9, 10, 12–14, 17–22). Other possible mechanisms for ginseng include increased production of corticotropin and cortisol in animals and humans (9, 12–14, 23, 24) and anabolic actions (stimulation of DNA, RNA, and protein synthesis in tissues) in animals (9–14, 17, 25, 26). Ginseng has shown immunoenhancing effects in animals and humans (12–14, 27–29) and antioxidant activity (increased liver glutathione content) in vitro and in animals (12–14, 30–33). Ginsenosides are also credited with stimulation of nitric oxide production in immune system cells, vascular endothelial cells, arteries, and erectile tissues (34–39). This mechanism, which was not discussed in the most recent reviews of ginseng, could account for many of the clinical effects observed. Thus, multiple mechanisms that have relevance to human physical performance may account for the possible antistress effects of ginseng.

The results of many animal studies of ginseng show improvements in exercise performance, but the use of large doses or parenteral administration (bioconversion of ginsenosides is known to occur in stomach acid and gut microbial actions before uptake) weakens extrapolation of these data to humans (1, 12–14). Previous reviews of ginseng and human physical performance reported mixed results (1, 12–14). An examination of available data reveals a dose-response and duration effect, which accounts for most of the variation in results. Data from available human studies (both controlled and uncontrolled) on *P. ginseng* preparations are shown in **Table 2**. As shown, properly controlled

TABLE 1
Herbs currently used to enhance physical performance

Herb	Reason for use	Potential or known hazards[1]
Arctic rose *(Rhodiola crenulata, R. rosea)*	Adaptogenic (antistress) properties, enhance endurance and strength	Occasional hypertension.
Ashwagandha (*Withania somnifera*)	Adaptogenic (antistress) properties, enhance endurance and strength	May potentiate effects of barbiturates.
Asian ginseng (also Chinese, Korean) (*Panax ginseng*)	Adaptogenic (antistress) properties, enhance endurance and strength	Possible adulteration with stimulant drugs; contraindicated in hypertension.
β-Sitosterol and other sterols (soy, alfalfa, and other plants)	Testosterone-like effect (anabolic)	None reported.
Chinese ephedra (mahuang) *(Ephedra sinica)*	Central nervous system stimulant, enhance endurance, strength, and body fat loss	Not recommended for long-term use; limit daily intake of total alkaloids to 120 mg in 4 equal doses. Seek advice from a health care practitioner before use if you are pregnant or nursing, or if you have high blood pressure, heart or thyroid disease, diabetes, difficulty in urination due to prostate enlargement, or if taking a monoamine oxidase inhibitor or any other prescription drug. Reduce or discontinue use if nervousness, tremor, sleeplessness, loss of appetite, or nausea occur. Not recommended for use by persons under 18 y of age. Keep out of reach of children.
Cordyceps (*Cordyceps sinensis*)	Adaptogenic (antistress) properties, enhance endurance and strength	None reported.
Potency wood (muira puama) (*Ptychopetalum olacoides*)	Testosterone-like effect (anabolic)	None reported.
Saw palmetto berries (*Serenoa repens*)	Testosterone-like effect (anabolic)	Rare cases of stomach upset. German Commission E suggests regular consultation with physician if one has an enlarged prostate, because *Serenoa* may treat symptoms without changing hypertrophy.
Schizandra (wu-wie-tza) (*Schisandra chinesis*)	Adaptogenic (antistress) properties, enhance endurance and strength	Rare cases of appetite suppression, stomach upset, urticaria.
Shilajit (mummio)	Adaptogenic (antistress) effects, enhance endurance and strength	Unknown.
Siberian ginseng (ci-wu-jia) (*Eleutherococcus senticosus*)	Adaptogenic (antistress) properties, enhance endurance and strength	Rare cases of insomnia. German Commission E contraindicates in high blood pressure.
Smilax (sarsaparilla) (*Smilax officinalis* or *medica*)	Testosterone-like effect (anabolic)	German Commission E warns of gastric irritation and temporary kidney impairment and potential drug interactions with hypnotics, digitalis glycosides, and bismuth (unsubstantiated)
Suma (*Pfaffia paniculata*)	Ecdysterone source, testosterone-like effect (anabolic)	None reported.
Tribulus terrestris (Tribestan)[2]	Increases testosterone (anabolic effects)	None reported.
Truffles	Contain androst-16-en-3-ol (weak androgen), testosterone-like effect (anabolic)	None reported.
Wild oats (*Avena sativa*) (combined with nettle root)	Testosterone-like effect (anabolic)	None reported.
Wild yam, Mexican yam (*Dioscorea villosa*)	Testosterone-like effect (anabolic)	None reported.
Yohimbe (*Pausinystalia yohimbe*)	α-Adrenergic agonist, potentiate caffeine and ephedrine effects, increase male performance	Not recommended for long-term use. Contraindicated in liver and kidney diseases and in chronic inflammation of sexual organs or prostate gland. May potentiate monoamine oxidase inhibitor drugs.

[1] From reference 8.
[2] Tribestan; Sopharma, Sofia, Bulgaria.

studies exhibiting statistically significant improvements in physical or psychomotor performance almost invariably used higher doses (usually standardized to ginsenoside content equivalent to ≥2g dried root/d), longer durations of study (≥8 wk), and larger subject numbers, indicating greater statistical power (9, 40–58). Also evident were the lower doses, durations, and subject numbers of studies that did not find any significant differences in performance, physiologic, or psychomotor measurements (46, 59–67).

Thus, under appropriate conditions, ginseng root extracts may increase muscular strength and aerobic work capacity. Requirements are sufficient daily dose (≥2000 mg *P. ginseng* root pow-

TABLE 2
Results of human studies with *Panax ginseng* on physical and mental performance[1]

Study (reference)	Subject *n*	Study design	Subject age range	Daily dose	Preparation type	Study duration	Effects (statistically significant unless otherwise stated)
Popov and Goldwag 1973 (9)	32 men	DB, PC	21–23 y	2-mL extract	40% ethanol tincture	Acute	Decreased errors in radio transmission of coded messages (17% compared with 31%); NS for number of characters transmitted
Sandberg 1974 (59)	30	DB, PC	Students	?	?	?	NS for spiral maze tracing test, letter cancellation test
Revers et al 1976 (40)	?	DB	Elderly	?	Standardized extract[2]	90 d	Improved vitality, alertness, rigidity, concentration, visual-motor coordination, positive outlook, visual and auditory reaction times
Simon 1977 [cited in Carr 1986 (13)]	36		Elderly	?	Standardized extract	90 d	Improved concentration, and mental accuracy; NS for attention
Bae 1978 [cited in Hobbs 1996 (12)]	32	DB, PC	21–23 y	?	?	?	Reduced telegraphy mistakes (17% compared with 31%); NS for mental concentration, coordination
Schmidt 1978 [cited in Hobbs 1996 (12)]	540	PC	?	?	?	?	Improved subjective and objective indexes; normalized blood glucose and blood pressure
Sandberg 1980 (42)	60	DB, PC	?	?	2 types of standardized extract	12 wk	Improved spiral maze tracing test, letter cancellation test, and oxygen metabolism (15-min step test)
Johnson 1980 [cited in Hobbs 1996 (12)]	38	?	Dental students	?	?	?	NS for mathematics performance, blood cortisol and epinephrines, proofreading error detection, mood, and fatigue indexes
Dorling et al 1980 (41)	60	DB, PC	22–80 y	?	Standardized extract	12 wk	Improved visual and auditory reaction times, postexercise recovery (stair climbing), 2-hand coordination, alertness, and subjective assessments
Forgo and Kirchdorfer 1981 (43)	20	NC	18–31 y	200 mg	Standardized extract	9 wk	Increased aerobic capacity; reduced lactate production, and heart rate
Forgo et al 1981 (44)	120	DB	30–60 y	200 mg	Standardized extract	12 wk	Improved vital capacity, forced expiration volume, maximum expiratory flow, maximal breathing capacity, reaction times, subjective assessments of mood, work output, sleep, concentration, vitality; NS for serum LH, FSH, testosterone, estradiol, blood chemistries
Forgo and Kirchdorfer 1982 (45)	30	NC	Elite young athletes	200 mg	Standardized extract, 4% or 7% ginsenoside content	9 wk	Improved aerobic capacity; reduced lactate production, and heart rate; NS for difference between 4% and 7% ginsenoside content
Hallstrom et al 1982 (46)	12 night shift nurses	DB, PC, CO	21–27 y	1200 mg	Korean white ginseng powder	3 d	Improved tapping rate test; NS for mood, somatic symptoms, blood glucose (all trends); negative effects on sleep quality
Forgo 1983 (47)	30 elite athletes	DB, PC	19–31 y	200 mg	Standardized extract	9 wk	Improved oxygen uptake, maximal breathing capacity, vital capacity, and forced expiration volume; reduced lactate production, and heart rate; NS for serum LH, testosterone, and cortisol
Knapik et al 1983 (60)	11 marathon runners	DB, PC	?	2000 mg	1.5% glycosides	4 wk	NS for R values, glucose, lactate, free fatty acids, glycerol, insulin, cortisol, and growth hormone
Teves et al 1983 (61)	12 marathon runners	DB, PC	22 ± 1 y	2000 mg	1.5% glycosides	4 wk	NS for run time to exhaustion, aerobic capacity, heart rate, V_E, and RPE
Murano et al 1984 (48)	65	NC	18–21 y, 38–70 y	2 capsules for 30 d, 1 capsule for 30 d	ARM229 standardized extract	60 d	Older group: improved performance in Cooper test (12-min run time); younger group: NS trend in Cooper and Harvard step tests
Forgo and Schimert 1985 (49)	28 elite athletes	DB, PC	20–30 y	200 mg	Standardized extract	9 wk	Improved oxygen uptake, forced expiration volume, vital capacity, visual reaction times, and heart rates
D'Angelo et al 1986 (50)	32	DB, PC	20–24 y	200 mg	Standardized extract	12 wk	Improved mental arithmetic calculations; NS trend for attention, choice reaction time, auditory reaction time; NS for tapping test, recognition, and visual reaction time

(*Continued*)

TABLE 2 (*Continued*)

Study (reference)	Subject *n*	Study design	Subject age range	Daily dose	Preparation type	Study duration	Effects (statistically significant unless otherwise stated)
Ng and Ng 1986 [cited in McNaughton et al 1989 (53)]	214	?	?	?	?	?	Improved endurance, maximal oxygen uptake, postexercise recovery, simple reaction time
Macareg and Ramos 1986 [cited in McNaughton et al 1989 (53)]	12	R, DB, PC, CO	?	?	?	?	NS for time to exhaustion, glucose, and lactate
von Ardenne and Klemme 1987 (51)	10	NC	50 y	200 mg	Standardized extract	4 wk	Improved resting PO_2 uptake (arteriovenous difference) by 29%
Tesch et al 1987 (52)	38	PC	50–54 y	80 mg	Standardized extract, vitamins, minerals	8 wk	Improved heart rate and lactate production (>180 W), RPE (60, 80, 120 W workloads); NS for lactate production up to 180 W
McNaughton et al 1989 (53)	15 women, 15 men	R, DB, PC, CO	?	1000 mg	Ginseng root powder	6 wk	Improved aerobic capacity, pectoral strength (27%), quadriceps strength (18%), postexercise recovery; NS for grip strength
Pieralisi et al 1991 (54)	50	R, DB, PC, CO	21–47 y	200 mg	Standardized extract plus DMAE, vitamins, minerals	6 wk	Improved total work load, time to exhaustion, aerobic capacity, ventilation, oxygen consumption, carbon dioxide production, lactate production, and heart rate; NS for RER
van Schepdael 1993 (55)	43 female triathletes	R, DB, PC, CO	24–36 y	400 mg	Standardized extract	20 wk	Prevented loss of physical fitness after 10 wk
Wiklund et al 1994 (56)	390	PC	Middle-age	200 mg	Standardized extract plus vitamins, minerals	12 wk	Improved alertness, relaxation, appetite, overall score, and general well-being (3 scales)
Morris et al 1994, 1996 (62, 65)	1 woman, 7 men	R, DB, PC	27 ± 5 y	8 or 16 mg/kg	*Panax quinquefolium* Water-ethanol extract	7 d	NS for cycle time to exhaustion and physiologic responses
Smith et al 1995 (63)	19 women	DB	26 ± 1 y	200 mg	Standardized extract	8 wk	NS for POMS and PANAS (psychological tests) and RPE
Engels et al 1995 (64)	19 women	DB	26 ± 1 y	200 mg	Standardized extract	8 wk	NS for exercise recovery (heart rate, lactate production, oxygen consumption, and ventilation)
Marasco et al 1996 (57)	625	R, DB, PC	18–65 y	200 mg	Standardized extract plus vitamins, minerals	12 wk	Improved quality of life, prevention of increased body weight and high blood pressure
Sorensen and Sonne 1996 (58)	112 healthy volunteers	R, DB, PC	>40 y	400 mg	Standardized extract	8–9 wk	Faster reaction times, better abstract thinking; NS for memory, concentration, well-being
Engels and Wirth 1997 (66)	36 men	R, DB, PC	?	200 or 400 mg	Standardized extract	8 wk	NS for oxygen consumption, RER, RPE, lactate, and heart rate during exercise
Allen et al 1998 (67)	8 women, 20 men	R, DB, PC, CO	23 ± 3 y	200mg	7% ginsenoside standardized extract	3 wk	NS for oxygen uptake, exercise time, workload, lactate production, hematocrit, heart rate, ratings of perceived exertion at 150 W, 200 W, or peak

[1] ?, data not listed or unavailable; CO, crossover; DB, double-blind; DMAE, dimethylaminoethanol; FSH, follicle stimulating hormone; LH, luteinizing hormone; NC, not controlled; PANAS, positive and negative affect schedule; PC, placebo-controlled; POMS, profile of mood survey; R, randomized; RER, respiratory exchange ratio; RPE, ratings of perceived exertion; VE, expiratory ventilation.

[2] Unless otherwise specified, standardized extract refers to G115, a proprietary ginseng extract standardized to 4% ginsenosides. G115 is a registered trademark of GPL Ginsana Products, Lugano, Switzerland, and Pharmaton Ltd, Switzerland.

der or an equivalent amount of root extract with standardized ginsenoside content), sufficient duration for effects to develop (≥8 wk), and sufficient intensity of physical or mental activity (especially in untrained or older subjects).

Studies finding performance enhancement from ginseng were not universally positive; some parameters were not significantly affected. For example, after baseline testing, McNaughton et al (53) randomly divided 30 subjects (15 females, 15 males) into 3 groups of 10 and administered placebo, Chinese ginseng, or Siberian ginseng (1 g/d of an uncharacterized powder of each) for 6 wk, when each subject was retested. Subjects were crossed over to the other 2 substances in 2 more 6-wk periods. Compared with placebo, Chinese ginseng significantly improved maximal oxygen uptake ($\dot{V}O_2$max; tested on a Monark model 686 cycle ergometer, Monark Exercise AB, Vansbro, Sweden), postexercise recovery (heart rate lowered 6 beats/min for the 6 min after exercise), pectoral strength (by 22% as measured by a dynamometer), and quadriceps strength (by 18% as measured by dynamometer). However, grip strength (measured by a Harpenden grip strength dynamometer) did not improve significantly (53).

Similarly, Forgo et al (44) studied 120 subjects aged 30–60 y for 12 wk in a double-blind study: subjects were given either placebo or 200 mg/d of a standardized ginseng extract. Supplementation was associated with significantly reduced reaction times for subjects aged 40–60 y but not for those aged 30–39 y. Men in this youngest group showed no significant effect from ginseng on pulmonary functions (vital capacity, forced expiratory volume, maximum expiratory flow, and maximum breathing capacity). Women aged 30–39 y and both sexes aged 40–60 y showed significant improvements in all 4 measurements of pulmonary function after 12 wk of supplementation. No significant changes by age or sex were found for serum concentrations of luteinizing hormone, testosterone, or estradiol. As with pulmonary function, subjective self-assessment showed significant improvements in women of all ages but only in men aged 40–60 y. Importantly, changes became significant after 6 wk of supplementation and were more significant at 12 wk, suggesting a slow-acting effect. Thus, studies lasting < 12 wk (46, 60–67) may not have been long enough to show a significant effect.

Is ginseng safe? A long tradition (> 2000 y) and an extensive history of use (millions of people, many elderly or infirm) suggests an affirmative answer (9–14), but recent reports have identified possible adverse effects. A "ginseng abuse syndrome" was described from case reports (68), but the reported symptoms of sleeplessness, nervousness, hypertension, skin eruptions, morning diarrhea, and euphoria may have been attributable to the very large caffeine intakes of most of the subjects. A few cases of estrogen-like effects (mastalgia and vaginal bleeding) were reported in postmenopausal women using topical creams or taking pills containing ginseng (69–73). Findings that a few ginseng products were adulterated with prescription medications (ephedrine or pseudoephedrine, for example) could account for unexplained side effects (12–15).

Conceivably, ginseng interacts with monoamine oxidase inhibitor medications, but more data are needed to confirm this (74). If true, another mechanism of action (inhibition of cyclic AMP phosphodiesterase) may account for some of the observed mental effects. In general, animal toxicity studies found ginseng to be very safe, with no teratogenicity or mutagenicity (12–14). In addition, the use of ginseng does not result in positive test results for any banned substances after urine testing of elite athletes, even though ginsenosides and their metabolites are detectable in the serum and urine of athletes after ingestion of ginseng products (75–77). Currently, there appears to be no risk of disqualification from drug-tested sporting events from use of ginseng (14). Given the generally positive results for ginseng on improving reaction times, long-term supplementation with standardized extracts may maintain or improve performance in skill sports that rely on quick reactions and quick thinking. This appears valid for recreational athletes > 40 y of age but less valid for younger athletes. Well-trained, elite athletes may not notice any benefits beyond a placebo effect except possibly during times of increased physical stress.

In summary, *P. ginseng* supplements may enhance physical and mental performance if taken long enough and in sufficient doses. Ginseng may exert greater benefits for untrained or older (> 40 y) subjects. Ginseng does not appear to exert any acute effects on physical performance. In general, ginseng supplements are safe, although individual variability exists and potentiation with stimulants such as caffeine may occur.

Siberian ginseng (E. senticosus or Acanthopanax senticosus)

Developed and studied by Russian researchers, Siberian ginseng is only distantly related to the *Panax* species, with both being members of the Araliaceae family. Siberian ginseng contains unique steroidal saponins termed eleutherosides that appear to be structurally similar to, but are distinct from, *Panax* ginsenosides (14, 17). A review by Brekhman and Dardymov (17) of early Soviet research on *Eleutherococcus* preparations involving thousands of subjects from entire towns, schools, factories, and hospitals in field tests showed improvements in subjects' work output and decreases in absences due to illness. These studies are difficult to interpret, however, because the data are almost inaccessible and the experimental designs are suspect. The results amount almost to epidemiologic findings, given the large number of subjects, but they offer only limited scientific evidence for the effectiveness of Siberian ginseng in improving human performance.

Other Soviet trials published in obscure symposia proceedings or Russian-language books were briefly reviewed by Walker (78) in a journal that was not peer reviewed. Improved muscular strength, resistance to fatigue, and recovery from exercise were reported for 35 weightlifters and wrestlers, 36 gymnasts, military personnel, 60 000 factory workers, and 52 laborers, but no experimental details were given. Thus, these results must be viewed with skepticism until more data become available.

Asano et al (79) administered 4 mL/d of an *Eleutherococcus* extract or placebo to 6 baseball players for 8 d in a single-blind, crossover study. $\dot{V}O_2$max was significantly improved, but the order of administration of control, placebo, and Siberian ginseng meant that an order effect rather than an ergogenic effect may have been observed. In another study, McNaughton et al (53) administered 1 g/d of Siberian ginseng powder for 6 wk to 30 subjects and used a randomized, double-blind, placebo-controlled, crossover design. Fifteen female and 15 male athletes from the Tasmanian State Institute of Technology were studied. Pectoral strength was increased by 13% and quadriceps strength rose 15%, with both changes statistically significant. However, $\dot{V}O_2$max, heart rate recovery from exercise, and grip strength were unchanged by Siberian ginseng in a comparison with the placebo group.

Dowling et al (80) studied the effects of administering 3.4 mL of an *Eleutherococcus* extract for 6 wk in 10 elite distance runners, who were compared with a matched placebo group (compliance was verified). The *Eleutherococcus* extract did not affect run time to exhaustion, heart rate, lactate production, ventilation measurements, oxygen consumption, ratings of perceived exertion, or respiratory exchange ratio. However, the authors stated that statistical power for measured indexes ranged from 0.16 to 0.52, casting great doubt on the ability of this study to detect any significant changes if they were present.

In 1996 a Siberian ginseng (*Eleutherococcus*) supplement identified as Ciwujia or *A. senticosus* (Endurox; Pacific Health Laboratories, Woodbridge, NJ) was heavily advertised as having caused a mean 43% increase in fat utilization and decreased blood lactate concentrations during graded cycle ergometry in 8 subjects (unpublished observations, 1996; *see* www.endurox.com/research). These results were obtained in China and publication in the *Chinese Journal of Hygiene Research* was reportedly in press. However, in early 1999 the Endurox Web site had no new information on publication of the results, and thus these enticing findings still await critical examination.

Given the paucity of human studies and the poor or inadequate experimental designs for studies investigating Siberian ginseng and physical performance, inferences must be conservatively drawn. This herb appears to possess either no ability or just a limited ability to improve the aerobic performance of well-trained individuals, but in one study with 30 subjects it was associated with improved muscular strength in untrained and trained subjects alike. Like *P. ginseng*, a slow-acting effect may become more apparent after 8 wk of observation, a time period not reached in controlled studies but achieved in Russian field studies. These conclusions must be considered as tentative until adequately controlled studies with sufficient statistical power and consistent identity and intake of eleutherosides are reported.

Mahuang (Chinese ephedra) and ephedrine alkaloids

Another important herb commonly used to enhance exercise performance is mahuang, or Chinese ephedra (*Ephedra sinica*). Ephedra species have a long tradition of use (>5000 y) for respiratory ailments (81). Unlike other herbs, the active ingredients are well characterized and consist of ephedrine and related alkaloids (mostly ephedrine, pseudoephedrine, norephedrine, and norpseudoephedrine) (81). Synthesized ephedrine alkaloids are found in hundreds of prescription and over-the-counter pharmaceutical products as antiasthmatic bronchodilators, antihistamines, decongestants, appetite suppressants, and weight-loss aids (81–83).

Recently, dietary supplements labeled as containing ephedra sold outside usual channels of commerce and marketed specifically to young adults to achieve a legal high, sexual ecstasy, euphoria, or increased energy have attracted considerable media and legislative scrutiny. In reality, these products are spiked with synthetic ephedrine alkaloids (ephedrine, pseudoephedrine, and phenylpropanolamine) and combined with other stimulants such as caffeine (Bucci, unpublished observations, 1997). Such products are not comparable with either traditional Chinese herbal products or other dietary supplements that contain only ephedra herb or standardized extracts (usually with ≤24 mg ephedrine and related alkaloids per unit dose). Dietary supplement trade associations have issued guidelines for safe use of ephedrine-containing products that are followed by most major companies. Typical guidelines suggest no more than 25 mg of ephedrine alkaloids per unit dose and no more than 100 mg total ephedrine alkaloids daily.

Ephedrine and related alkaloids are sympathomimetic agents that mimic epinephrine effects (81–83). Like other stimulants, they may cause adverse effects when used chronically and in sustained high doses (>100 mg/d), especially when overdosed. Nervousness, anxiety, heart palpitations, headaches, nausea, hyperthermia, hypertension, cardiac arrhythmias, and occasional deaths have occurred with ephedrine alkaloid overdoses (81–83). Dietary supplement products reported to the Food and Drug Administration as causing side effects have almost always contained large amounts of caffeine (150–300 mg per unit dose) (L Bucci, unpublished observations, 1997). Thus, particular caution must be exercised when consuming products containing both ephedrine alkaloids and caffeine.

Studies examining the effects of acute administration of ephedrine, pseudoephedrine, or phenylpropanolamine on exercise performance (time to exhaustion, muscular strength) in humans have shown no enhancements at usual dosages considered to be safe (≤120 mg) (84–88). Sidney and Lefcoe (84) administered 24 mg ephedrine to 21 males and found no significant differences, compared with placebo, in muscle strength, endurance or power, lung function, reaction time, hand-eye coordination, anaerobic capacity, speed, cardiorespiratory endurance, $\dot{V}O_2$max, ratings of perceived exertion, or recovery. Blood pressure and heart rate were slightly, but significantly, elevated and learning of simple psychomotor tasks was facilitated. Bright et al (85) found no significant changes in heart rate, blood pressure, glucose, or insulin after acute administration of 60 or 120 mg pseudoephedrine to 6 males undergoing submaximal exercise. Sinus arrhythmias were increased at the high dose.

In another study, DeMeersman et al (86) found no significant effects of acute ephedrine administration on fuel homeostasis, ventilation, oxygen consumption, heart rate, blood pressure, or ratings of perceived exertion in 10 subjects engaged in graded cycle ergometry. More recently, Swain et al (87) administered typical doses of pseudoephedrine (1 and 2 mg/kg) and phenylpropanolamine (0.33 and 0.66 mg/kg) to 10 trained cyclists. Subjects underwent bicycle ergometer testing and urine drug testing after ingesting either placebo or the compound doses. There was no significant difference between trials for either compound in $\dot{V}O_2$max, ratings of perceived exertion, maximum systolic or diastolic blood pressures, peak pulse rate, or time to exhaustion. However, the 1-mg/kg dose of pseudoephedrine significantly raised peak systolic blood pressure by an average of 10.6 mm Hg. Urine concentrations of each compound were variable between subjects and persisted the day after exercise. Gillies et al (88) measured the effect of 120 mg pseudoephedrine or placebo on 1 h of high-intensity exercise (40-km cycle ergometry) in 10 subjects in a randomized, double-blind, placebo-controlled, crossover study design with a nonexercise control period. Performance in a time trial or muscle function was not changed significantly by pseudoephedrine. Exercise caused increases in urinary concentrations of pseudoephedrine compared with those during resting states.

In summary, individual ephedrine alkaloids at doses greater than those found in herbal extract products resulted in no enhancement of physical performance. There remains a possibility that mental functions were improved, which in effect would cause a placebo-like response in real-life settings such as sporting events or training sessions.

Combining ephedrine with caffeine has been associated with improvements in physical performance. Bell et al (89) studied 8 male subjects in a repeated-measures design with high-intensity exercise on a cycle ergometer. Placebo administration led to a 12.6 ± 3.1 min time to exhaustion, whereas 5 mg caffeine/kg (14.4 ± 4.1 min) or 1 mg ephedrine/kg (15.0 ± 5.7 min) alone caused nonsignificant increases in times to exhaustion. However, the caffeine-ephedrine combination significantly improved time to exhaustion (17.5 ± 5.8 min). Ratings of perceived exertion were significantly lower after the combination, but heart rate was significantly elevated after both caffeine and the combination. Caffeine and the combination increased lactate, glucose, glycerol, and free fatty acid concentrations, similar to other trials (1–4, 13, 82). Oxygen consumption, carbon dioxide production, minute ventilation, and respiratory exchange ratio were unchanged by caffeine, ephedrine, or the combination. Catecholamine availability was increased after the combination, suggesting central nervous system stimulation. Thus, the combination of ephedrine with caffeine, but not either compound alone, was associated with prolonged exercise time to exhaustion. The doses used are easily

reached by doubling the serving size of typical sports supplements containing both ephedrine and caffeine.

In obese women consuming a low-energy diet, an ephedrine and caffeine combination (2 × 25 mg and 2 × 200 mg, respectively) increased heart ejection fraction during cycle ergometer exercise but not during rest (90). When yohimbine (2 × 5 mg) was added to ephedrine and caffeine, cardiac performance was attenuated during rest and cardiac work during cycle ergometer exercise was increased, whereas the ejection fraction was decreased. Yohimbine is sometimes added to dietary supplements containing ephedrine and caffeine to try to prolong effects or reduce possible side effects, such as increases in heart rate and blood pressure. In this study, ephedrine and caffeine only weakly affected cardiovascular measurements during rest or exercise, which corresponds with results of other studies.

Another aspect of ephedrine that is ignored in reviews on ergogenic effects is its documented thermogenic ability both without (91–96) and with (97–99) caffeine. This ability leads to reduced body fat during hypoenergetic diets in obese subjects (100, 101), especially when ephedrine is combined with caffeine (102–107), theophylline (108), or caffeine and aspirin (109–113). Some athletes (especially bodybuilders) want to maximize body fat loss while maintaining muscle mass, and frequently resort to supplements containing ephedrine and caffeine to aid in fat loss. Evidence from obese subjects has shown that lean mass is preserved better with ephedrine-containing combinations during weight loss (103, 106, 114); obese subjects consuming hypoenergetic diets reproducibly showed increased loss of body fat from ephedrine-containing preparations. It is outside the scope of this review to describe in detail studies of ephedrine or caffeine in weight-loss settings, and application to lean athletes or sports settings was not studied until recently.

An unpublished study examined the effects of a placebo meal, a meal with ephedrine and caffeine, and a meal with *p*-synephrine and caffeine on body temperature, metabolic rate, and other indexes for 195 min. Ten healthy, active females and 10 healthy, active males (recreational athletes) were studied in a randomized-order, double-blind, placebo-controlled, crossover study design (115). All active ingredients were from standardized herbal sources only, and they contained other herbal ingredients with hypothetical synergistic effects (yohimbe for yohimbine, *Ledebouriella divaricata*, *Schizonepeta tenuifolia*, and quercetin). Ephedrine (24 mg) was from *E. sinica*, *p*-synephrine (10 mg) was from zhi shi or bitter citrus (*Citrus aurantium*), caffeine (300 mg) from guarana (*Paullinia cupana*) and green tea (*Camellia sinensis*), and yohimbine (12 mg) from yohimbe (*Pausinystalia yohimbe*) herbal extracts. In comparisons with the placebo meal, a significant increase in core body temperature (≈0.5°C) was found for each herbal group. The ephedrine-plus-caffeine group showed a significant increase in metabolic rate, respiratory exchange ratio, heart rate, and blood pressure, whereas the *p*-synephrine-plus-caffeine group exhibited only a smaller increase in blood pressure and improved vigor on a Profile of Mood Survey. When results were extrapolated to 24 h, the *p*-synephrine group had a significant increase in resting metabolic rate. These findings suggest that herbal combinations containing ephedrine plus caffeine or *p*-synephrine plus caffeine and other herbs may reproduce short-term thermogenic and metabolic effects that are conducive to body fat loss; this conclusion is supported by results with other healthy volunteers and obese subjects given ephedrine, caffeine, or both in purified form. Other studies have verified that ephedrine from purified or herbal (*E. sinica*) sources has equivalent bioavailability in humans (116, 117).

Ephedrine is a banned substance for amateur sporting events, and use of mahuang (Chinese ephedra) from dietary supplements is likely to disqualify athletes in drug-tested events. Recently, another herb, *Sida cordifolia*, was said to contain ephedrine alkaloids, but firm data on amounts are lacking, even from suppliers. Actual analysis of *S. cordifolia* has found varying results. One report found ephedrine and related alkaloids (118) and another found the alkaloid vasicine, but not ephedrine (119). Thus, *S. cordifolia* and other *Sida* species may contain ephedrine alkaloids. It is not known whether ingestion of dietary supplements containing *Sida* herbs will cause a positive drug test in athletic events, but the possibility is likely.

Other herbs

A variety of other herbs and herbal combinations have been used to enhance physical performance, but few have been tested in human clinical trials. Rationales for use of other herbs as well as herbs that have already been reviewed are shown in Table 1. Other herbs generally fall into 1 of 2 categories: *1*) adaptogen or tonic (ginseng-like) or *2*) anabolic (increase muscle mass). Tonic herbs are presumed to enhance aerobic performance and anabolic herbs are presumed to mimic or be converted in the body into anabolic steroids, mostly for use in bodybuilding and weightlifting communities. Although anecdotal and testimonial "evidence" abounds, the rationale for use of other herbs is strictly hypothetical, conjectural, or based on results of animal studies.

Administration of 1.5 g/d for 75 d of *Rhodiola crenulata* root extract led to increased work capacity (run time to exhaustion), $\dot{V}O_2$max, and ventilation in a comparison with placebo (120). An unpublished study found that a combination of wild oats (*Avena sativa*), stinging nettle root (*Urtica dioica*), sea buckthorn (*Rhamnus frangula*), and vitamin C produced improvements in strength, anaerobic power, endurance time, and feelings of well-being (Exsativa; Swisstonic, New York, 1995). This investigation was a double-blind, crossover study that lasted 6 wk, but no experimental details, including error or statistical analysis, were given, and thus no valid conclusions can be drawn. Walker reported Soviet tests with schizandra (*Schisandra chinensis*) that led to better 3000-m run times and tests with combinations of Siberian ginseng and *Aralia*, *Rhaponticum*, *Rhodiola*, and schizandra that led to better performance, but no details were given (78).

Other adaptogenic herbs, such as ashwagandha (*Withania somnifera*), have shown antistress effects in animal tests (including swim times and anabolic activity) that were equal to or better than results with Korean ginseng (26). Interestingly, both ashwagandha and ginseng root powders were shown to contain starch. At the high doses (100 mg/kg) used in animal swim time studies, the results may have been due to carbohydrate supplementation rather than inherent effects of herbal constituents. This may be a good example of why animal research must be interpreted carefully before results are extrapolated to humans.

Shilajit (mummio) is a tarry exudate from rock crevices found at high altitudes in the Himalayas and Caucasus mountains that is derived from long-term humification of *Euphorbia* and *Trifolium* (clover) plants (121). Eastern European weightlifters have been using mummio as part of an "herbal anabolic stack" to promote better strength, recovery, and muscular hypertrophy. Traditional Ayurvedic use of shilajit as a tonic has some support from studies

TABLE 3
Antioxidant activities in humans of selected herbs

Herb	Reference	Antioxidant compounds and activity
Tea (green, black, oolong) (*Camellia sinensis*)	126, 127	Epigallocatechin gallate, and theaflavin gallates, and thearubigens (flavonoid polyphenols): LDL oxidation, 8-hydroxyguanosine
Ginkgo biloba	7, 128	Flavonoid glycosides and ginkgolide terpenoids: scavenge superoxides, hydroxyl radicals, nitric oxide, and oxoferryl radicals; peroxidation, LDL oxidation; and cyclosporin A-induced peroxidation
Garlic (*Allium sativa*)	129	Glutathione, sulfhydryls, selenium: lipid peroxidation
Maritime pine (*Pinus maritima*)	130	Procyanidins: lipid peroxidation
Quercetin (many plants)	127	LDL oxidation
Grape skins and seeds (*Vitis* spp.)	127, 130	Procyanidins and resveratrol: LDL oxidation
Tannic acid (many plants)	127	LDL oxidation
Milk thistle seed (*Silybum marianum*)	127	Silymarin flavolignan: LDL oxidation
Tomatoes	131	Lycopene: most efficient singlet oxygen scavenger
Green vegetables and marigold flowers	131, 132	Lutein: free radical scavenger

of the humic acids, fulvic acids, coumarins, and triterpenes that have shown antistress effects in animals (121). However, human data on this and other adaptogenic herbs are sorely lacking.

Other herbs or plant extracts are believed to provide or mimic testosterone-like (anabolic) effects in humans because of their similarity of chemical structure. These herbs contain sterols, ecdysterone, or steroidal saponins (Table 1). Anabolic effects are particularly sought by bodybuilders and weightlifters. With the exception of truffles, which contain trace amounts of a very weak androgenic steroid, androst-16-en-3-ol (122), there is no evidence to support the conversion of plant sterols to testosterone in the human body (122, 123). Possible steroid receptor effects from ecdysterone in animal studies (124) indicate that further study is necessary to rule out a possible effect of certain steroid-like compounds found in these herbs that is mediated by receptor or feedback loop regulation rather than bioconversion into steroids. Possible mechanisms include anticatabolic effects from blocking cortisol receptors and stimulation of anabolic or androgenic steroid receptors, similar to that seen for ginsenosides.

An extract of *Tribulus terrestris* (Tribestan; Sopharma, Sofia, Bulgaria) has gained recent interest following promotional presentations of English language translations of Bulgarian pharmaceutical company research. Reportedly, the *Tribulus* extract elevated circulating testosterone and luteinizing hormone amounts that were depressed in men who were part of infertile couples (125). Until the original research becomes available for scrutiny, these results must be regarded with caution, and extrapolations to normal, exercising individuals should not be made. In summary, hypothetical mechanisms, but a paucity of data in humans, characterize the known evidence for other herbs purported to affect human physical performance.

RESEARCH RECOMMENDATIONS

Because consumers have access to a wide variety of herbal dietary supplements, and because there is some mechanistic research from in vitro or animal studies, future studies would be most pertinent if they would focus on outcomes important to consumers. These outcomes should include measurements of exercise performance (time to exhaustion, strength or torque changes for resistance training, changes in body composition, hormone concentrations, race times, mood changes, and neuromuscular changes). Such studies should examine dose-response curves, which are lacking for most herbal supplements. A necessary criterion is identification of hypothetical or known active ingredients, which should measure multiple types of marker compounds (eg, steroidal saponins and phenolic acid and total fiber). Herbs contain a wide variety of potentially active or supportive compounds in addition to the hypothetical active compounds that may provide important attributes not immediately apparent. Standardized herbal extracts, if extracted in a consistent manner, are the best type of material for studies at this time.

Instead of a single, very large study, a series of smaller studies with sufficient statistical power to evaluate performance measurements is probably the desirable approach and more feasible as well. In such studies, specific questions and concerns are more easily investigated and study populations can be better defined. As herbal supplements with apparent merit are identified, further detailed studies on mechanisms would be more efficiently performed.

Many herbs have well-documented antioxidant activities in humans (**Table 3**) (126–132). Whether these activities would affect human physical performance or protect human tissues from exercise-induced free radical damage is unexplored. However, given the protective effects shown by the essential nutrient antioxidants (carotenoids, tocopherols, ascorbate, and selenium) during exercise in humans (133–135) and the performance-enhancing attributes of sulfur-based antioxidants (136–138), there is enough evidence to suspect that plant antioxidant preparations may have a similar ability and further studies are warranted. Combinations of herbs with vitamins, minerals, metabolites, or other herbs is another promising area of research that is virtually unexplored.

I suggest that a unified theory of the mechanistic actions of herbs will eventually become apparent. Major commonalities between herbs to investigate should include their *1*) antioxidant effects, *2*) hormone or other regulatory receptor effects, and *3*) specific enzyme inhibitions or enhancements. Combinations of the 3 may account for most of the effects seen for herbs.

SUMMARY AND CONCLUSIONS

Except for studies on the effects of ginseng, there is a dearth of controlled scientific studies on the effects of herbs or herbal extracts on human physical performance. Factors that have discouraged controlled investigations of herbs and physical performance include difficulties with taxonomic classification, identification and consistency of active components of herbs,

variability in growing conditions, lack of dose-response data in humans, limited duration of response studies, lack of interest from funding agencies, negative bias from investigators, and economic disincentives for pharmaceutical exploration of unpatented natural products. As a result, much of the human research on herbs and exercise performance has occurred outside of the United States, which has prevented widespread dissemination of research results because of language barriers and inaccessibility of journals. Nevertheless, considerable research has been performed with humans with the various preparations of ginseng, which allows some conclusions to be drawn.

When doses of *P. ginseng* are given that resemble amounts used in traditional Chinese medical practice (3–9 g of dried root powder or equivalent amount of ginsenosides from standardized extracts) for durations of ≥8 wk, some aspects of performance, both physical and mental, may be enhanced or their decline prevented. However, the higher incidence of positive effects in physical performance studies of subjects not living in the United States may reflect life-long differences in diet (such as food fortification) (139) that would make ginseng more efficacious. Evidence for this idea is seen in studies using ginseng extracts combined with vitamins, minerals, and other metabolites (52, 54, 56).

Although Siberian ginseng (*E. senticosus*) and *R. crenulata* extracts both have at least one positive outcome in human studies, the evidence is preliminary or contradictory at this time. Herbal stimulants, such as mahuang or its constituent alkaloids, do not appear to have affected physical performance significantly in a limited number of studies. However, a combination of ephedrine alkaloids with caffeine led to significant changes in performance and physiologic parameters over that obtained for either ingredient alone in several studies. Other herbs remain completely unstudied for outcomes on physical performance in humans.

In conclusion, a comprehensive literature review found that *P. ginseng* products taken with sufficient dosage (200–400 g/d of standardized *P. ginseng* root extracts containing ≥4% ginsenosides) and duration (≥8 wk) may prevent deleterious effects of overtraining or enhance physical performance, especially in persons > 40 y of age. Recommendations include use by trained subjects undergoing continuous training or untrained subjects embarking on a strenuous exercise program. In brief, herbal supplementation to enhance human physical performance has had little scientific study, but it represents a large and valid field for future study.

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