

Ephedra and Ephedrine for Weight Loss and Athletic Performance Enhancement: Clinical Efficacy and Side Effects

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Ephedra and Ephedrine for Weight Loss and Athletic Performance Enhancement: Clinical Efficacy and Side Effects

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Preface

The Agency for Healthcare Research and Quality (AHRQ), through its Evidence-Based Practice Centers (EPCs), sponsors the development of evidence reports and technology assessments to assist public- and private-sector organizations in their efforts to improve the quality of health care in the United States. The reports and assessments provide organizations with comprehensive, science-based information on common, costly medical conditions and new health care technologies. The EPCs systematically review the relevant scientific literature on topics assigned to them by AHRQ and conduct additional analyses when appropriate prior to developing their reports and assessments.

To bring the broadest range of experts into the development of evidence reports and health technology assessments, AHRQ encourages the EPCs to form partnerships and enter into collaborations with other medical and research organizations. The EPCs work with these partner organizations to ensure that the evidence reports and technology assessments they produce will become building blocks for health care quality improvement projects throughout the Nation. The reports undergo peer review prior to their release.

AHRQ expects that the EPC evidence reports and technology assessments will inform individual health plans, providers, and purchasers as well as the health care system as a whole by providing important information to help improve health care quality.

We welcome written comments on this evidence report. They may be sent to: Director, Center for Practice and Technology Assessment, Agency for Healthcare Research and Quality, 6010 Executive Blvd., Suite 300, Rockville, MD 20852.

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Structured Abstract

Objectives. To assess the efficacy of herbal ephedra-containing dietary supplements and ephedrine on weight loss and athletic performance, through comprehensive literature review and synthesis of evidence. We also assessed safety of these products through review of adverse events reported in clinical trials, published case reports of adverse events, reports on file with the U.S. Food and Drug Administration (FDA), and a file of reports kept by a manufacturer of ephedra products, Metabolife.

Search Strategy. We searched for studies of herbal ephedra and ephedrine using the following electronic databases: Medline, EmBase, BIOSIS, Allied & Complementary Medicine Database (AMED), MANTIS, the Cochrane Controlled Clinical Trials Register Database, International Pharmaceutical Abstracts, Pascal, and SciSearch. We were able to obtain unpublished studies by posting notices in relevant journals and through contacts on our Technical Expert Panel. The FDA provided us with copies of over 1,000 adverse event reports (AERs) related to herbal ephedra and 125 adverse event reports related to ephedrine. The Metabolife files contained 18,502 cases.

Selection Criteria. Only studies of weight loss that were controlled trials of human subjects with treatment of at least eight weeks duration were accepted to assess efficacy. For assessment of athletic performance, only controlled trials of human subjects were accepted, but no minimum follow-up was specified. Reports of adverse events from controlled trials were included regardless of treatment duration. We reviewed all available reports of death, myocardial infarction (heart attack), cerebral vascular accident (stroke), seizure, and serious psychiatric illness reported to the FDA prior to September 30, 2001 and contained in their ephedra or ephedrine files, and all case reports identified in our literature search .

Data Collection and Analysis. We found 59 articles that corresponded to 52 controlled clinical trials of ephedrine or herbal ephedra for weight loss or athletic performance. Forty-six were controlled trials assessing ephedra or ephedrine for weight loss. Of these, 20 were excluded from pooled analysis because they had treatment durations of less than eight weeks. Thirteen articles corresponding to six trials were excluded for a variety of reasons. For the outcome of weight loss the effects of ephedra/ephedrine were examined in six different types of comparisons: (1) ephedrine versus placebo; (2) ephedrine plus caffeine versus placebo; (3) ephedrine plus caffeine versus ephedrine; (4) ephedrine versus other active treatment; (5) ephedra versus placebo; and (6) ephedra plus herbs containing caffeine versus placebo. Only four placebo-controlled trials assessed the combination of ephedra plus herbs containing caffeine, and only one trial assessed ephedra without herbs containing caffeine. Because of their small number and heterogeneity, seven athletic performance trials were compared and contrasted using only a narrative review and were not synthesized statistically. We also conducted a pooled meta-analysis on those adverse event symptoms that occurred frequently in the controlled trials.

In reviewing the individual adverse event reports, we searched for documentation that an adverse event had occurred, documentation that the subject had consumed ephedra within 24 hours prior to the adverse event, or a toxicological examination revealing ephedrine or one of its associated products in the blood or urine. We also sought evidence that an adequate investigation

had assessed and excluded other potential causes. Cases that met all these criteria were labeled “sentinel events.” Cases that met the first two criteria but had other possible causes of the event were labeled “possible sentinel events.” Classification as a sentinel event does not imply a proven cause and effect relationship. We used clinical judgment of expert clinicians to assess whether other causes had been adequately evaluated and excluded.

Main Results. *Weight Loss.* Short-term use of ephedrine, ephedrine plus caffeine, or dietary supplements containing ephedra with or without herbs containing caffeine is associated with a statistically significant increase in short-term weight loss (compared to placebo). The addition of caffeine to ephedrine is associated with a statistically significant modest increase in short-term weight loss. The observed effects on weight loss of ephedrine plus caffeine and ephedra-containing dietary supplements with or without herbs containing caffeine are approximately equivalent: a weight loss approximately two pounds per month greater than that with placebo, for up to four to six months. No studies have assessed the long-term effects of ephedrine or ephedra-containing dietary supplements on weight loss; the longest published treatment duration was six months.

Athletic Performance. The effect of herbal ephedra-containing dietary supplements on athletic performance has not been assessed. The few studies that assess the effect of ephedrine on athletic performance have included only small samples of fit individuals (young male military recruits) and have assessed its effect only on very short-term immediate performance. These data support a modest effect of ephedrine plus caffeine on very short-term athletic performance. One study reported the addition of caffeine to ephedrine is necessary to produce an effect on athletic performance. No studies have assessed the sustained use of ephedrine on performance over time.

Safety Issues. There is sufficient evidence from controlled trials to conclude that the use of ephedrine and/ or the use of ephedra-containing herbal supplements or ephedrine plus caffeine is associated with two to three times the risk of nausea, vomiting, psychiatric symptoms such as anxiety and change in mood, autonomic hyperactivity, and palpitations. The controlled trials studied relatively few people and in aggregate were insufficient to evaluate events with a risk of less than 1.0 per one thousand.

The majority of case reports are insufficiently documented to make an informed judgment about a relationship between the use of ephedrine or ephedra-containing dietary supplements and the adverse event in question. Prior ephedra consumption was associated with two deaths, four myocardial infarctions, nine cerebrovascular accidents, one seizure, and five psychiatric cases as sentinel events. Prior consumption of ephedrine was associated with three deaths, two myocardial infarctions, two cerebrovascular accidents, one seizure, and three psychiatric cases as sentinel events. We identified 43 additional cases as possible sentinel events with prior ephedra consumption and 7 additional cases as possible sentinel events with prior ephedrine consumption. About half the sentinel events occurred in persons aged 30 years or younger.

Conclusions. Ephedrine, ephedrine plus caffeine, and ephedra-containing dietary supplements with or without herbs containing caffeine all promote modest amounts of weight loss over the short term. There are no data regarding long-term effects on weight loss. Single-dose ephedrine plus caffeine has a modest effect on athletic performance. The available trials do not provide any evidence about ephedrine or ephedra-containing dietary supplements, as they are used by the general population, to enhance athletic performance. Use of ephedra or ephedrine plus caffeine is

associated with an increased risk of gastrointestinal, psychiatric, and autonomic symptoms. The adverse event reports contain a sufficient number of cases of death, myocardial infarction, cerebrovascular accident, seizure, or serious psychiatric illness in young adults to warrant a hypothesis-testing study, such as a case-control study, to support or refute the hypothesis that consumption of ephedra or ephedrine may be causally related to these serious adverse events.

Contents

Evidence Report	1
Chapter 1. Introduction	3
Purpose	3
Scope of Work	3
Background	3
The Problem of Obesity	5
Enhancing Physical Performance	6
History and Pharmacology	7
Chapter 2. Methodology	13
Original Proposed Key Questions	13
Weight Loss	13
Athletic Performance	13
Safety Assessment	13
Technical Expert Panel	14
Assessment of Adverse Events	14
Literature Search	15
Additional Sources of Evidence	16
Article Review	17
Extraction of Study-Level Variables and Results	17
Meta-Analysis	18
Selection of Trials for Meta-Analysis	18
Stratification of Interventions	19
Weight Loss Effect Size	20
Performance of Meta-Analysis	21
Analysis of Dose	23
Publication Bias	23
Meta-Regression	23
Safety Assessment	24
Controlled Trial Adverse Events	24
Case Report Adverse Events	26
Peer Review	32
Chapter 3. Results	81
Results of Literature Search	81
Efficacy Analysis	81
Adverse Events Analysis	81
Efficacy	82
Weight Loss	82
Athletic Performance	85
Safety Assessment	86
Controlled Trials	86
Case Reports	88

Chapter 4. Limitations ..	215
Chapter 5. Conclusions ..	219
Efficacy ..	219
Weight Loss ..	219
Athletic Performance ..	220
Adverse Consequences ..	220
Chapter 6. Future Research ..	223
References ..	225
Evidence Tables ..	233
Acronyms ..	247

Appendix 1. Bibliography

Appendix 2. Metabolife Serious Adverse Events

Appendix 3. Reviewer Comments

Tables

Table 1. Herbs containing caffeine commonly combined with ephedra in products marketed for weight loss or improved physical performance	11
Table 2. Technical expert panel members	35
Table 3. Technical expert panel suggestions about data collection	36
Table 4. Measures used in assessing causality	37
Table 5 Ephedra/ ephedrine search methodology	38
Table 6 Ephedra/ephedrine search methodology – additional databases	39
Table 7. Categories of adverse events	40
Table 8. Report reviewers	41
Table 9. Weight loss trial inclusion results	113
Table 10. Ephedrine versus placebo	114
Table 11. Publication bias tests	115
Table 12. Ephedrine + caffeine versus placebo	116
Table 13. Ephedrine + caffeine versus ephedrine	117
Table 14. Ephedrine versus another active weight loss therapy	118
Table 15. Ephedra versus placebo	119
Table 16. Ephedra + herbs containing caffeine versus placebo	120
Table 17. Meta-regression results	121
Table 18. Exercise trials by Bell and colleagues	122
Table 19. Summary table of meta-analysis of adverse events reported controlled trials	123
Table 20. Summary table of other of adverse events reported in controlled trials	124
Table 21. Distribution of adverse events in the FDA file according to the Excel Spreadsheet	125
Table 22. Evidence table of case reports	127
Table 23. Summary of adverse events with ephedra consumption	181
Table 24. Summary of adverse events with ephedrine consumption	182
Table 25. Summary of adverse events not reviewed in detail	183
Table 26. Summary data of key variables from Metabolife file analysis	185
Table 27. Comparison of serious cases identified by RAND and by Metabolife	187
Table 28. Summary of Metabolife medical records	191

Figures

- Figure 1. Screening form for literature 43
- Figure 2. Quality review form for literature 45
- Figure 3a. Adverse events analysis form for death, MI, stroke cases 51
- Figure 3b. Adverse events analysis form for seizure cases 57
- Figure 3c. Adverse events analysis form for psychiatric cases 63
- Figure 4. Brief data collection form for case reports 69
- Figure 5. Examples of MIPER files 71
- Figure 6. Example of duplicate case 77
- Figure 7. Metabolife record screener form 79
- Figure 8. Literature flow 202
- Figure 9. Ephedrine versus placebo – forest plot 203
- Figure 10. Ephedrine versus placebo – funnel plot 203
- Figure 11. Ephedrine + caffeine versus ephedrine alone – forest plot 204
- Figure 12. Ephedrine + caffeine versus placebo – funnel plot 204
- Figure 13. Ephedrine + caffeine versus ephedrine alone – forest plot 205
- Figure 14. Ephedra + herbs containing caffeine versus placebo – forest plot 206
- Figure 15. Ephedra + herbs containing caffeine versus placebo – funnel plot 206
- Figure 16. Effect sizes by comparison group 207
- Figure 17a. Flow of evidence for adverse events analysis, part 1 208
- Figure 17b. Flow of evidence for adverse events analysis, part 2. 209
- Figure 17c. Flow of evidence for adverse events analysis, part 3. 210
- Figure 18. Flow of MIPER ID Numbers 211

Summary

Overview

At the direction of the funding agencies (National Institute of Health Office of Dietary Supplements (ODS), the National Center for Complementary and Alternative Medicine (NCCAM), and the Agency for Healthcare Research and Quality (AHRQ)), and in consultation with our Technical Expert Panel, we addressed research questions regarding the efficacy of herbal ephedra and synthetic ephedrine for weight loss and athletic performance through a comprehensive literature review and synthesis of evidence. We assessed the safety of these products through review of clinical trials. Meta-analysis was performed where appropriate. In addition, we reviewed herbal ephedra- and ephedrine-related adverse events reports on file with the U.S. Food and Drug Administration (FDA), published case reports, and reports to a manufacturer of ephedra-containing products. It is expected that the results of this review will be used to direct further research.

Reporting the Evidence

The following questions were provided to us by the funding agencies and guided this evidence report.

Weight Loss

1. *What is the evidence for efficacy of ephedra-containing dietary supplement products in weight loss, over a sustained period of time?*
2. *Can efficacy for weight loss be attributed to ephedra alone, or ephedra in combination with other ingredients (e.g., caffeine)?*
3. *Does ephedra have additive effects with other agents?*
4. *What dosage levels of ephedra are necessary to achieve weight loss?*

Athletic Performance

1. *What is the evidence for efficacy of ephedra-containing dietary supplement products in terms of energy enhancement and enhancement of athletic performance, over a sustained period of time?*
2. *Can efficacy for energy enhancement and enhancement of athletic performance be attributed to ephedra alone, or ephedra in combination with other ingredients (e.g., caffeine) that produce energy enhancement and/or enhancement of athletic performance?*
3. *Does ephedra have additive effects with other agents?*
4. *What dosage levels of ephedra are necessary to achieve energy enhancement and enhancement of athletic performance?*

Safety Assessment

1. *Does use of ephedra-containing dietary supplement products over a sustained period of time increase the risk of cardiovascular disease (CVD) or other serious and life-threatening events in specific populations?*
2. *What populations are at risk of CVD and other life-threatening events through use of ephedra over a sustained period of time?*

3. *Can the risk for adverse events in these populations be attributed to ephedra alone, or in combination with other ingredients (e.g., caffeine)?*
4. *Does ephedra have additive effects with other agents?*
5. *What dosage levels of ephedra produce risk of CVD or other life-threatening events?*
6. *Do ephedra-containing dietary supplement products alter physiologic markers of cardiovascular function?*
7. *What are the metabolic actions of ephedra, so as to explain its beneficial and adverse effects?*

In addition to answering these 15 questions about ephedra-containing dietary supplement products, we were also asked to synthesize the available information on the same questions for the purified alkaloid, ephedrine.

After searching published reports, journal articles, conference presentations, and various sources of unpublished studies, we identified 54 controlled clinical trials of ephedrine or herbal ephedra for weight loss or athletic performance in humans. The Food and Drug Administration provided us with copies of over 1,000 adverse event reports (AERs) related to herbal ephedra and 125 AERs related to ephedrine. These reports often included interviews with patients and/or family members, extensive medical records, and copies of product labels. We identified 70 case reports in the literature and received a disk of 15,951 reports containing 18,502 cases from Metabolife, a manufacturer of ephedra products.

Methodology

Efficacy. Data for the efficacy analysis were abstracted from reports of controlled trials onto a specially designed form containing questions about the study design, the number of patients and comorbidities, dosage, adverse events, the types of outcome measures, and the time from intervention until outcome measurement. We selected the variables for abstraction with input from the project's technical experts. Two physicians, working independently, each extracted data from the same reports and resolved disagreements by consensus.

In selecting studies for the meta-analysis of weight loss efficacy, we considered only those trials of at least eight weeks treatment duration. Our technical expert panel judged that shorter treatment durations were insufficient to assess weight loss. In selecting studies on athletic performance, we found that these studies varied widely with respect to intervention. Because of this heterogeneity, we compared and contrasted these studies in a narrative review, rather than performing a statistical synthesis.

The effects of ephedra/ephedrine on weight loss were examined in six different types of comparisons: (1) ephedrine versus placebo; (2) ephedrine plus caffeine versus placebo; (3) ephedrine plus caffeine versus ephedrine; (4) ephedrine versus other active treatment; (5) ephedra versus placebo; and (6) ephedra plus herbs containing caffeine versus placebo. The last comparison subgroup contained only a single trial; thus, effect sizes were estimated only for the first five. The effect size was calculated by dividing the outcome of a study (e.g., difference in weight loss per month between the two groups) by its standard deviation, which produces a unitless measure that is useful when comparing studies that assess outcomes (such as weight)

that are similar but are measured differently (e.g., weight loss in pounds versus change in body mass index). Effect sizes were pooled separately for each of the five comparison subgroups. In addition, we used meta-regression to conduct a cross-subgroup synthesis on the effect sizes of the subgroups with a placebo comparison: ephedrine versus placebo; ephedrine plus caffeine versus placebo; and ephedra plus herbs containing caffeine versus placebo.

Safety. We reviewed each report of a controlled trial (regardless of treatment duration) for data on adverse events. Adverse events were recorded onto a spreadsheet that identified each study arm, the description of the adverse event as listed in the original article, and the numbers of subjects and adverse events in each arm. We then compared event rates in the ephedra or ephedrine groups to those in the placebo groups. We conducted a meta-analysis on those adverse event symptoms for which appreciable numbers of events were noted in the controlled trials.

Adverse event reports compiled by the Food and Drug Administration (FDA) concerning ephedra or ephedrine were also reviewed by our physician reviewers. Within the time and resource constraints of this report, we reviewed all available reports of death, myocardial infarction (heart attack), cerebral vascular accident (stroke), seizure, and serious psychiatric illness filed prior to September 30, 2001. We also reviewed published case reports as well as event reports filed with Metabolife, a manufacturer of ephedra-containing products. After screening, all case reports were subjected to a review.

Based on input from our technical expert panel and the literature on methods to assess adverse event reports, we identified three important criteria for inclusion of such reports:

1. Documentation of an adverse event that met our selection criteria.
2. Documentation that the person having the adverse event took an ephedra-containing supplement or ephedrine within 24 hours prior to the event (for cases of death, myocardial infarction, stroke, or seizure).
3. Documentation that alternative explanations for the adverse event were investigated and were excluded with reasonable certainty.

We classified cases that met all three of these criteria as “sentinel events.” Cases in which the event might have had other possible causes but the pharmacology of ephedrine could have contributed were classified as “possible sentinel events.” Cases of death, myocardial infarction, cerebral vascular accident, and seizure were reviewed by internists, with additional review (as indicated) by a cardiologist, neurologist, or rheumatologist. Psychiatric cases were reviewed by a psychiatrist specializing in addictions and a psychologist with expertise in substance abuse. The criterion for use within 24 hours was not required for psychiatric cases.

Findings

Efficacy for Weight Loss. We identified 46 controlled trials that assessed use of ephedra or ephedrine used for weight loss. Of these, 20 were excluded from pooled analysis because they had a treatment duration of less than eight weeks. Six additional trials were excluded for a variety of other reasons. Of the remaining 20 trials included in the meta-analysis, only five tested

herbal ephedra-containing products. Together, these 20 trials assessed 678 persons who consumed either ephedra or ephedrine. The majority of studies of both ephedra and ephedrine are plagued by methodological problems (particularly, high attrition rates) that might contribute to bias. These methodological limitations must be considered when interpreting any conclusions regarding the efficacy of these products. Nevertheless, the evidence we identified and assessed supports an association between short-term use of ephedrine, ephedrine plus caffeine, or dietary supplements that contain ephedra with or without herbs containing caffeine and a statistically significant increase in short-term weight loss (compared to placebo). Adding caffeine to ephedrine modestly increases the amount of weight loss. There is no evidence that the effect of ephedra-containing dietary supplements with herbs containing caffeine differs from that of ephedrine plus caffeine: Both result in weight loss that is approximately two pounds per month greater than that with placebo, for up to four to six months. No studies have assessed the long-term effects of ephedra-containing dietary supplements or ephedrine on weight loss; the longest duration of treatment in a published study was six months.

Efficacy for Physical Performance Enhancement. The effect of ephedrine on athletic performance was assessed in seven studies. No studies have assessed the effect of herbal ephedra-containing dietary supplements on athletic performance. The few studies that assessed the effect of ephedrine on athletic performance have, in general, included only small samples of fit individuals (young male military recruits) and have assessed the effects only on very short-term immediate performance. Thus, these studies did not assess ephedrine as it is used in the general population. The data support a modest effect of ephedrine plus caffeine on very short-term athletic performance. No studies have assessed the sustained use of ephedrine on performance over time. The only study that assessed the additive effects of these agents reported that ephedrine must be supplemented with caffeine to affect athletic performance.

Safety Issues. The data on adverse events were drawn from clinical trials and case reports published in the literature, submitted to the FDA, and reported to Metabolife, a manufacturer of ephedra-containing supplement products. The strongest evidence for causality should come from clinical trials; however, in most circumstances, such trials do not enroll sufficient numbers of patients to adequately assess the possibility of rare outcomes. Such was the case with our review of ephedrine and ephedra-containing dietary supplements. Even in aggregate, the clinical trials enrolled only enough patients to detect a serious adverse event rate of at least 1.0 per 1,000. For rare outcomes, we reviewed case reports, but a causal relationship between ephedra or ephedrine use and these events cannot be assumed or proven.

Evidence from controlled trials was sufficient to conclude that the use of ephedrine and/or the use of ephedra-containing dietary supplements or ephedrine plus caffeine is associated with two to three times the risk of nausea, vomiting, psychiatric symptoms such as anxiety and change in mood, autonomic hyperactivity, and palpitations.

The majority of case reports are insufficiently documented to make an informed judgment about a relationship between the use of ephedrine or ephedra-containing dietary supplements and the adverse event in question. For prior consumption of ephedra-containing products, we identified two deaths, four myocardial infarctions, nine cerebrovascular accidents, one seizure, and five psychiatric cases as sentinel events; for prior consumption of ephedrine, we identified

three deaths, two myocardial infarctions, two cerebrovascular accidents, one seizure, and three psychiatric cases as sentinel events. We identified 43 additional cases as possible sentinel events with prior ephedra consumption and 7 additional cases as possible sentinel events for prior ephedrine consumption. About half the sentinel events occurred in persons aged 30 years or younger. Classification as a sentinel event does not imply a proven cause and effect relationship.

We did not assess the plethora of additional symptoms that have been reported in the published literature and the FDA Medwatch file for ephedra-containing dietary supplements and ephedrine products.

Future Research

Our analysis of the evidence reveals numerous gaps in the literature regarding the efficacy and safety of ephedra-containing dietary supplements. First, long-term assessments of the effectiveness of herbal ephedra or ephedrine for promoting weight loss are lacking. We identified no study with a treatment duration longer than six months. To improve health outcomes and reduce the risk of morbidities associated with being overweight, sufficient weight loss (5 to 10 percent of body weight) and long-term weight maintenance are necessary. Therefore, the benefit of ephedrine or herbal ephedra-containing dietary supplements for health outcomes is unknown.

Evidence regarding the effect of herbal ephedra or ephedrine on physical performance that reflects its use in the general population (repeated or long-term use by a representative sample) is also needed.

In order to assess a causal relationship between ephedra or ephedrine consumption and serious adverse events, a hypothesis-testing study is needed. Continued analysis of case reports cannot substitute for a properly designed study to assess causality. A case-control study would probably be the study design of choice.