BACKGROUND

Problem Statement

According to the U.S. Centers for Disease Control (CDC), seventy five percent (75%) of the nation's health care spending was spent to cover the cost of chronic diseases affecting Americans, such as coronary artery disease, dementia, age-related eye disease, and osteoporosis. These diseases are potentially avoidable with some types of preventive care [1]. Preventable chronic diseases also reduce the total productivity of the U.S. workforce by more than $260 billion annually [1]. Yet, the U.S. only spends 2.9% of total health care expenditures on preventive care services annually according to the statistics collected by the Organization for Economic Co-operation and Development (OECD). This is comparable to other OECD countries but is only a fraction of what is needed [2].

Despite the U.S. health care system not having as strong an emphasis on preventive medicine as could be desired, the role of preventive care in maintaining individual and overall health and wellness as opposed to a continued reactive approach focused on single-event interventions is gaining more purchase. Most Americans are well aware of the issues facing the country's current health care system, including growing costs, denied tests and treatments, fragmented care, less time available for a patient-physician relationship, medical errors, and other inefficiencies. However, the last decade has shown that important cultural, technological, and demographic trends have increasingly put more control of their health into the hands of patients. This transformation has had an enormous impact on how medicine is practiced today (e.g., telemedicine) and how the health care system, as a whole, operates.

This shift has been driven by stakeholders looking for better ways to control escalating health care costs by identifying people at higher risk of disease early and working to minimize their chances of experiencing costly events, using more targeted or personalized solutions. One solution that is accessible to Americans today is the availability of certain dietary supplement products that have been scientifically shown to help reduce this risk. Dietary supplements, based on the Dietary Supplement Health and Education Act (DSHEA) of 1994, are defined as products that are orally ingested and contain nutrients or other dietary components meant to supplement the diet [3]. Dietary supplements come in many forms, including tablets, capsules, liquids, and powders and the active components of dietary supplements are often derived from nutrients found in food including vitamins, minerals, fiber and carbohydrates, fatty acids, proteins, and amino acids [3].

In the last several decades, and especially in the past decade, a significant amount of clinical research has been published exploring the association between the use of certain dietary supplements by certain subjects at high-risk of disease, particularly any effect on disease event

occurrence or event risk biomarkers. What is known is that many disease events require costly treatments, especially those associated with chronic diseases, and preventing at least some of these events from ever occurring would necessarily have an impact on future health care spending. In this update study, we examine the potential health care cost savings that could be realized if certain at-risk individuals were to use certain dietary supplements that have been shown to lower disease event risk. Specifically, this report will examine evidence that demonstrates that the use of key dietary supplement ingredients can reduce the direct and indirect medical costs associated with coronary artery disease (CAD), age-related cognitive decline disorders, age-related eye disease, diabetes, osteoporotic fractures, irritable bowel syndrome, and inadequate choline intake among expectant mothers in the United States.

Research Methodology

The overarching research methodology used in this economic report is based on a health-to-wealth Cost-Benefit Analysis (CBA) model created in 2013 to address this topic [4]. This model was built to allow the comparison of dietary supplement users versus non-users in terms of any changes in disease-attributed risk which in turn would imply that associated disease treatment and management costs were different as well. Specifically, this CBA can be used to assess various use (and non-use) scenarios and to identify the potential savings or loss that can be realized in one scenario versus another. The determination of whether a given dietary supplement regimen is cost-effective is based on the risk level faced by the user's risk profile, the supplement's effectiveness at reducing the risk of the potential supplement user and the magnitude of the economic consequences (costs) that could be incurred if the potential user did not use the supplement and experienced a medical event [4].

This issue is similar to the basic methodology of most clinical studies; the treatment's effect on the outcome of a given event can be assessed when a treatment regimen is applied to one group versus a control group. From these types of analyses, risk—and possible risk reduction—can be calculated using a cost-benefit model which can be useful to key decision makers (including patients, health care professionals, governments, insurance companies, and employers) in determining if a given regimen is cost-effective.

To find the true effect size of treatment with a given dietary supplement, a rigorous search for clinical research studies and meta-analyses of clinical research studies for each of the seven interventions was conducted to deduce the expected efficacy of dietary supplementation on the incidence of disease events that required medical treatment and/or resulted in increased costs due to disease management and productivity losses. The aim was to collect a comprehensive set of studies that represented the totality of evidence of efficacy for a given dietary supplement's effects on the relative risk of a specific disease event.

In summary, the process of deriving the risk reduction metric for each of the dietary supplements assessed followed the same general process: relevant and representative clinical studies and meta-analyses were identified through a rigorous search exercise that studied any effects on disease event occurrence and calculating an aggregated measure of relative risk between dietary supplement users versus non-users from the set of identified studies. Specifically, we undertook the following steps to derive the expected risk reduction metrics for use in the cost savings model:

Review of the scientific literature related to the given chronic disease and the dietary supplement of interest

We performed a rigorous scientific literature search to build a database of key studies (both clinical studies of various study protocol types and meta-analyses) that investigated the potential for a causal relationship between supplement intake and the incidence of specific health conditions of interest. Types of studies considered include randomized controlled trials, meta-analyses of randomized control trials, observational epidemiologic studies, and other types of clinical trials adhering to accepted scientific methodologies. Inclusion was independent of whether the findings were positive, negative, or null. The search exercise used the U.S. National Library of Medicine's PubMed database. All studies reviewed were retrieved between November 1, 2021, and April 15, 2022.

Identification of a representative set of qualified studies that investigated a causal relationship between supplement intake and the incidence of specific health conditions of interest

Once the database of studies was created, each study's title, abstract, and, in some cases, full text was thoroughly assessed to determine whether the study directly tested for a quantifiable relationship between supplement use and the incidence of a specific chronic disease event, either directly or indirectly through a specified biomarker. Specifically, a study was considered qualified for inclusion if it directly tested a relationship between the intake of the dietary supplement of interest and a potential effect on the likelihood of a disease event occurring, independent of the direction of the relationship. Both primary and secondary outcomes were considered. Typically, it was observational epidemiologic studies and randomized clinical trials that fit this criterion. If such studies were not found, then studies were reviewed that tested for a potential causal relationship between supplement intake and the level of a biomarker that has been correlated with the relative risk of a disease event. The authors strove to include studies that were similar in methodology in a given meta-analysis in an attempt to control for observational variance. In addition, the research team strove for an ideal of exhaustive inclusion of all studies, although that cannot be guaranteed because of time and resource constraints. The authors make no claims of endorsing the specific findings of any scientific study reviewed, and any exclusion of relevant studies is accidental and should not be read as a judgment of any type.

Weighting and aggregation of the qualified study findings in order to determine an overall expected impact of dietary supplement intervention on disease event occurrence

The next step in the process was to conduct the actual meta-analysis, meaning that each qualified study's reported effect size was weighted by the reported precision of its findings and the size of its sample population in order to derive an overall expected risk reduction (RR) metric. A random-effects meta-analysis approach was used in cases where a dietary supplement had a significant number of scientific/clinical studies that directly explored the specific question that this study aims to address [5]. This approach allowed us to properly combine the results of a number of studies that addressed the same research question, even though each study varied in terms of sample size, study protocol, research team, and a host of other qualities. The variance in study characteristics was addressed by controlling for inter-study and intra-study variance, which was expected to provide a more reliable estimate of the overall effect of the intervention [5]. Meta-analyses are increasingly common in the dietary supplement literature, and their - prevalence is a testament to the growth in research & development investment made by the dietary supplement industry to demonstrate the efficacy of its products. In cases where there was a recently published meta-analysis on the same topic, the authors defaulted to these findings because they were independently conducted and peer-reviewed, and it was assumed that their findings were objective.

Health Care Cost Savings Scenario Analysis

The key criterion for a given study's inclusion in the cost models was a measure of relative risk (RR) given use of the supplement of interest versus non-use of the supplement. RR can be used to derive the number needed to treat (NNT) given a certain baseline disease risk level [5]. The NNT is the total number of people within a target cohort who would have to adopt a specified dietary supplement regimen in order to realize one avoided undesired event. This criterion was selected as the variable of focus in the present study because it was easy to associate an expected health care cost with each person expected to experience an event. For example, if a given dietary supplement had an NNT of 100, this would mean that 100 people would need to be supplemented to avoid one major disease event in the target population.

Once the NNT for a given dietary supplement regimen was determined, the number of potentially avoided events if everybody in a given population were to use the supplement at the daily intake level found to be effective could be calculated. From the expected cost per event, the total avoided costs could also be estimated. For example, consider the case of magnesium. It has been found that 13.12 million people aged 55 and over had documented coronary artery disease (CAD) in 2021 and has been estimated that 15.8 million of the people in this group will experience a new CAD event by 2030. Thus, if the total population had used magnesium at preventive daily intake levels, over 91,000 CAD events would have been avoided based on the supposition from current scientific literature

that the expected relative reduction of risk of experiencing a CAD event was 5.34%. This implies an NNT metric of 144 people who needed to be treated to avoid one such event. Given that the cost of each CAD event averaged $31,517 in 2021, the net potentially avoided direct and indirect medical costs would have been approximately $1.830 billion in 2021. Refer to Table 11 for a detailed description of the derivation of the relative risk metric for magnesium intake.

Once the expected effect size was determined from the literature, the potential cost savings derived from dietary supplement usage at preventive daily intake levels among a particular high-risk cohort was calculated and compared with zero usage [155]. The calculation of total cost savings is straightforward – the total expenditure on chronic disease events at zero usage MINUS total expenditure on chronic disease events given the use of dietary supplements at protective levels and the expected reduction in chronic disease events because of reduced risk PLUS the cost of dietary supplement use by the entire target high-risk cohort EQUALS potential net cost savings [155].

Accordingly, if the potential net cost savings was positive, the dietary supplement regimen in question was considered an effective means of reducing overall disease-related individual lifetime costs and total social health care costs [155]. Of course, the prior cost-benefit analysis approach makes the assumption that in the supplementation scenario, the entire population of the target high-risk cohort used the given dietary supplements at protective intake levels, and this was compared to zero use in that population segment. In other words, the calculated net savings is actually the maximum potential net savings theoretically achievable. However, because it is likely that a percentage of the target high-risk cohort are already regular users of the dietary supplement in question at various intake levels, that share of the target population would have already reduced its risk of experiencing a disease event and would be already realizing its risk-reducing benefits, while the remainder of the potential regular users has yet to realize the potential preventive benefits from regular use of the given dietary supplements at protective intake levels. Because avoided expenditures and net cost savings are a function of the total number of people in the target population using the dietary supplements, the calculation of avoided health care expenditures and net cost savings yet to be realized is simply a proportional adjustment of the total potential avoided expenditures and net cost savings by the number of current users. These yet-to-be-realized adjustments are also calculated in each of the scenario analyses conducted in this study and are reflected in their respective chapters.

Research Limitations and Assumptions

It should be noted that each nutrient explored in this study was analyzed independently, and comparisons between them may be unwarranted. The definition of disease-attributed events and the associated per-person costs of treatment vary by disease condition, among other factors; thus, derived benefits and costs are not comparable across disease conditions. In addition, health benefits

of using different supplements, such as omega-3 fatty acids and magnesium in combination for reducing the risk of a single disease, such as CAD, may not be additive. This study does not control for average food intake of these ingredients because it is assumed that most of the clinical studies did not fully control for food intake either, suggesting that the observed effect sizes has taken into account some food-based intake. Finally, variability due to differences in sample size, research methodologies and study protocols, and patient population characteristics among the included studies was high, making comparison of the relative efficacy of dietary supplements unadvisable.

However, there is enough evidence to suggest that the net cost savings realizable if people were to use a combination of the studied dietary supplements is highly likely to be greater than that realized from using any single one. Certainly, more research is required to determine if cost savings from use of multiple supplements is additive (the sum of the savings from each supplement), synergistic (the savings from multiple supplements is higher than the sum of the savings from each supplement due to offsetting effects/differences in their mechanisms of action), or antagonistic (the net savings from using a combination of supplements is lower than the sum of the saving from each one). The authors do not endorse the specific findings of any scientific study reviewed.

Regarding cost estimate forecasts, expected compound annual growth rates (CAGR) were derived from a historic assessment of population growth rates and price inflation growth. Specifically, health care costs per person are expected to grow at an average annual growth rate of 2.2% from 2022 to 2030 based on the observed average price inflationary growth rate over the last 10 years. Given current inflation rates, we consider this expected growth rate to be conservative. Also, this growth rate was applied for all procedures for all conditions assessed in this study. Growth in the targeted population was expected to occur at the average annual growth rate of the population as a whole during the forecast period, and it was assumed that growth in disease incidence is equal to population growth based on a review of population growth and disease incidence trends. Dietary supplement retail prices were expected to grow at a compound annual growth rate of 2.2% per year, the same as price growth in general.