Examination of the Transtheoretical Model (TTM) on Fruit and Vegetable Intake

by

Jun Ma

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Jun Ma, Ph.D.

University of Nebraska, 2002

Advisor: Nancy M. Betts

Nutrition researchers are becoming increasingly interested in using the Transtheortical Model to study dietary change. This model has been popular in addictions research for 20 some years, with smoking cessation being most extensively researched. This two-phase dissertation project was designed to tackle some of the limitations discovered in a review of existing applications of the model in dietary change. Phase I was a longitudinal mail survey study with responses collected at baseline, one month, and six months. At baseline, 197 completed and returned the survey (response rate = 40%) while the number dropped to 107 and 77 at one month and six months, respectively. Measures included, two staging algorithms, a stages-of-change questionnaire, a decisional balance scale, a self-efficacy scale, a processes-of-change scale, and a food frequency questionnaire. The measures were adapted from previous research and data verifying their reliability and validity were reported. Major statistical methods used included factor analysis, cluster analysis, analysis of variance (ANOVA) with Scheffe's test, student and paired t-tests, and chi-square test. A three-stage schema (i.e., unconcerned, exploring, and action-oriented) with possible subgroupings was suggested for fruit and vegetable intake. Differences in decisional balance and the use of experiential processes of change appeared to differentiate the unconcerned and exploring stages, whereas the exploring and action-oriented stages differed more in self-efficacy, the use of behavioral processes of change, and the intake of fruits and vegetables. These

findings warrant further validation. Phase II was an Internet-based intervention study, comparing a stage-tailored and a nontailored intervention as well as a no-intervention control. One hundred and ten eligible individuals were recruited at baseline (response rate = 51%) and randomly assigned to the study groups. Attrition occurred at the one-month and six-month follow-ups with no differentiations seen by study group. Measures validated in Phase I were adopted and data were examined using ANOVA with Scheffe's test and multivariate ANOVA with Bonferroni's correction. Unfortunately, few intervention effects were detected; strategies that could improve the intervention effectiveness were suggested.

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JM

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INTRODUCTION

A voluminous body of evidence has shown the protective effects of fruit and vegetables on chronic diseases such as cardiovascular disease, cancer, and diabetes (Block et al., 1992; Frasao, 1995; National Research Council, 1989). Fruit and vegetables are excellent sources of complex carbohydrate, micronutrients, and dietary fiber while low in total and saturated fat. The importance of these foods has been consistently stressed in the current issues of US dietary guidelines (Butrum, 1988; Human Nutrition Information Services, 1992; US Depts of Agriculture and Health and Human Services, 1995). However, translating scientific knowledge and dietary guidelines into desirable dietary changes by the masses is a major challenge for a nation. In this country, the nationwide 5-A-Day campaign has been ongoing since 1991 (Havas et al., 1995), with the aim of increasing average Americans' fruit and vegetable consumption. Nonetheless, recent national studies showed that although a trend toward increase is apparent, the typical American diet is still limited in number of servings and/or variety of foods from the fruit and vegetable groups (Kant et al., 1991; Krebs-Smith et al., 1995 and 1997; Ma J and Betts NM, 1998).

The gap between knowledge and behavior implies that current methods of delivering nutrition messages are not as effective in promoting behavior change as expected. One reason accounting for the ineffectiveness is that most dietary interventions are directed toward taking action while most of the population is not ready to act. Promotion of dietary changes may be particularly challenging. Most dietary changes rarely result in immediate and obvious physical and/or psychological benefits. The

appeal of potential future well-being may be too nebulous to have an influence on dietary behaviors for many.

To date, intervention strategies that can be readily modified for use in both large-scale campaigns and individualized counseling to improve eating behaviors are yet to be developed. Many ongoing activities promoting large-scale change in American eating behavior have focused mostly on issuing and disseminating health and nutrition recommendations. However, implementing this approach alone has generally resulted in frustrating outcomes. Theory-based nutrition interventions are gaining increasing interest because they have demonstrated promising success with promoting healthy eating patterns in the general public (Glanz, 1985; Glanz and Eriksen, 1993). Emerging as an innovative framework, the Transtheoretical model (TTM) (Prochaska, 1991; Prochaska and DiClemente, 1982), more widely known as the Stages of Change theory, has been studied and shows promise for modifying addictive behaviors, cigarette smoking cessation in particular (DiClemente et al., 1991; Prochaska et al., 1988). In the domain of eating behaviors, application of TTM has resulted in dietary fat reductions (Curry et al., 1992; Glanz et al., 1994; Greene et al., 1994; Lamb et al., 1996; Sporny et al., 1995;). Until now, only limited research has investigated the utility of the model in assessing the intake of fruit and vegetables (Brug et al., 1997; Domel et al., 1996; Glanz et al., 1994; Laforge et al., 1994) and, to a lesser degree, in promoting their intake (Campbell et al., 1994). This shortcoming justifies the initial motivation and overall goal for the current research.

REVIEW OF LITERATURE

For the purpose of elucidating the significance of this project, this chapter will review previous literature relevant to the following five subjects: 1) protective effects of fruit and vegetables; 2) fruit and vegetable intake in the U.S.; 3) the transtheoretical model (TTM); and 4) TTM and fruit and vegetable intake.

I. Protective Effects of Fruit and Vegetables

The health benefits of fruit and vegetables have been documented in numerous epidemiologic and laboratory studies and more supportive evidence continues to emerge. Perhaps the most convincing evidence relates to the risk of cancer, which ranks the second leading cause of death in the U.S. (Centers for Disease Control and Prevention, 1999). Data from studies with different experiment designs strongly and consistently indicate that fruits and vegetables are protective against cancer of a variety of anatomical sites, more specifically, the respiratory system (lung cancer and larynx cancer); digestive system (oral and pharyngeal cancer, esophageal cancer, stomach cancer, colorectal cancer, gall-bladder cancer, and pancreatic cancer); and reproductive system and related sites (cervical cancer, ovarian cancer, breast cancer, and prostate caner) (Block et al., 1992; Steinmetz and Potter, 1996). Although to a lesser degree, data also exist showing inverse associations of the intake of fruit and vegetables with the incidence of cardiovascular disease and stroke (Gillman et al., 1995; Law and Morris, 1998).

Epidemiological evidence on protection against cancer

Despite dietary patterns in Mediterranean countries vary widely in consumption of specific foods and in nutrient intake, they share a common characteristic, namely,

richness in fruits and vegetables and low content of saturated fatty acids (Kittler and Sucher, 2000). Because of the low incidences of several cancers and heart disease observed around Mediterranean regions, an etiological association with diet was postulated and has attracted extensive research attention.

By integrating a series of hospital-based case-control studies conducted in northern Italy between 1983-1990, Negri et al. (1991) examined the relationship of cancer risk with vegetable and fruit consumption. The cases had been diagnosed with one of the following cancers: oral cavity and pharynx (n = 119); esophagus (n = 294); stomach (n = 564); colon or rectum (n = 1,079); liver (n = 258); gall-bladder (n = 41); pancreas (n = 303); larynx (n = 149); breast (n = 2,860); endometrium (n = 567); ovary (n = 742); prostate (n = 107); bladder (n = 365); kidney (n = 147); thyroid (n = 120); Hodgkin's disease (n = 72); non-Hodgkin lymphomas (n = 173); or myelomas (n = 117). Controls were 6,147 patients who were admitted for acute non-neoplastic conditions and had no long-term dietary modifications. Information about socioeconomic characteristics, lifestyle habits, and the weekly frequency of consumption of selected indicator foods were obtained from all subjects. After adjustment for age, sex, area of residence, education and smoking, multivariate relative risks (RR) of the selected cancers were computed for the medium and upper tertiles of vegetable intake (< 7; 7; > 7 portions/wk) and fruit intake (< 7; 7-13; ≥14 portions/wk) with the lower tertile of intake as the reference category (RR = 1). For all cancers except gallbladder, it was observed that the higher the vegetable consumption the lower the risk. Relative risk estimates for the upper tertile of vegetable intake ranged from 0.2 for cancers of the esophagus, liver, and larynx

to 0.7 for breast cancer. According to RR estimates, high vegetable consumption was associated with lower risk of all epithelial cancers, but no protection for non-epithelial lymphoid neoplasmas or myelomas (RRs > 1.0). Fruit consumption was found to be most protective against cancers of the upper digestive and respiratory tracts, with RR estimates for the upper tertile of the intake being between 0.2-0.3 for cancers of the oral cavity, pharynx, esophagus, and larynx. High fruit intake also had significant protective effects for cancer of the liver (RR = 0.6), pancreas (RR = 0.5), prostate (RR = 0.4), kidney (RR = 0.6) and bladder (RR = 0.4). This study is limited in its generalizability and its ability to suggest biological mechanisms. However, the findings add support to existing evidence that fruit and vegetables are beneficial for reducing the incidence of cancer, even though their protection effects may affect different cancer sites.

More than a score of prospective cohort studies also examined the relationship between fruit and vegetable consumption and cancer risk and the majority found an inverse association as reviewed by Block et al. (1992) and Steinmetz and Potter (1996). Shibata et al. (1992) followed a cohort of 11,580 residents of a retirement community beginning in 1981 until 1989 or the diagnosis of cancer, whichever occurred first. The same questionnaire was mailed to the cohort initially and periodically throughout the follow-up phase. The following information was requested: demographic characteristics; medical history; use of cigarettes; use of vitamin supplements; and usual frequencies of consumption of 59 food items containing primarily fruits and vegetables rich in either vitamin A and its precursor or vitamin C. The daily frequencies were derived for

consumption of five food categories - all vegetables and fruits, all vegetables, all fruits, dark-green vegetables, and yellow vegetables. By referring to the US Department of Agriculture tables of food composition, average daily intake of beta-carotene and vitamin C was estimated for each subject. Only people who had no history of cancer and were free from cancer at the time of entry into the study were recruited. By the end of the study, 1,335 cancer cases were diagnosed, including 219 breast cancer cases, 208 prostate cancer cases, 202 colon cancer cases (97 men and 105 women), 164 lung cancer cases (94 men and 70 women), and 71 male bladder cancer cases. Separately for each sex, the age- and smoking-adjusted relative risks (RR) of cancers of all sites, the lung, colon, prostate, and bladder were computed for tertiles of the intakes of the five food groups, dietary beta-carotene, and dietary vitamin C and for vitamin supplement (vitamins A, C, & E) users and nonusers. A protective effect of dark green vegetables on colon cancer and that of vitamin C supplements on bladder cancer were observed for men. For women, significant inverse associations were seen for all vegetables and fruits, for fruits alone, and for dietary vitamin C with all sites combined and colon cancer alone. Also, fruit intake alone was protective against breast cancer, and supplement use of vitamins A and C were in significant inverse associations with colon cancer of women. In conclusion, in this cohort of older adults who were predominantly female, Caucasian, and of the upper-middle socioeconomic class, a protective effect against cancer was discovered for vegetable and fruit intake as well as supplement use of vitamin C, with the effect being stronger for women than for men. The findings suggested association of reductions in not only

overall cancer but also cancers of specific sites with fruit and vegetable intakes.

Ample evidence exists showing the protective effects of fruits and vegetables on specific cancers, for example, lung cancer (Pillow et al., 1997), colorectal cancer (Potter et al., 1993; Trock et al., 1990; Witte et al., 1996), breast cancer (Djuric et al., 1998), and prostate cancer (Jain et al., 1999). The literature suggests that protective effects against cancer are stronger for vegetables, especially those rich in antioxidants and/or flavonoids, than for fruits (American Institute of Cancer Research, 1997; Block et al., 1992; Steinmetz and Potter, 1996).

Epidemiological evidence on protection against cardiovascular/cerebrovascular disease

In addition to its inverse association with cancer risk, consuming fruit and vegetables is also linked with reduced risks of cardiovascular disease (e.g., ischemic heart disease and myocardial infarction) and cerebrovascular disease such as stroke. Law and Morris (1998) quantitatively analyzed the epidemiological data from previous cohort studies that determined relationship of fruit and vegetable consumption or marker nutrients with the incidence or mortality of ischemic heart disease in attempt to quantify the size of the relationship. Beta-carotene and other carotenoids, vitamin C, fruit and vegetable fiber, and potassium were identified as marker nutrients of overall intake of fruit and vegetables which are the primary contributors of these nutrients to total dietary intake. A standard expression of the diet-disease association was utilized, that is, the relative risk of ischemic heart disease at the 90^{th} percentile of consumption to that at the 10^{th} percentile in a population ($RR_{10\text{-}90}$). In addition to food and/or marker nutrient intakes, serum or plasm concentrations of marker nutrients were also analyzed in the

same way in relation to the risk of ischemic heart disease.

It was reported that the RR_{10-90} estimates all fell in the range of 0.81 and 0.88 with a median of 0.85 for six dietary markers, including all fruit, all vegetables, carotenoids, vitamin C, fruit fiber, and vegetable fiber. The RR_{10-90} was 0.57 (95% CI 0.47-0.69) for serum concentration of carotenoids and 0.93 (95% CI 0.72-1.21) for vitamin C. Not only did the study confirm the notion that fruit and vegetables convey important though modest protection against ischemic heart disease but also quantitatively identified a 15% lower risk of the disease at the 90^{th} than the 10^{th} percentile of the intake. The 90^{th} percentile of fruit and vegetable intake in the pooled data was eight servings per day, which is within the recommended range of 5-9 servings/d and a realistic goal in motivated people.

Cerebrovascular disease ranks the third leading cause of death in the U.S., superseded only by heart disease and cancer. Primary intervention is of vital importance for reducing the morbidity and mortality rates of the disease because of the lack of effective therapies. By studying the stroke incidence rates among immigrants, environmental factors, including diet, were implicated in the initiation and prevention of stroke (Syme et al., 1975). Gillman and colleagues (1995) analyzed data from the Framingham Study, a longitudinal study, specifically examining the effect of fruit and vegetable consumption on stroke incidence among 832 men aged 45-65. All subjects entered the study between 1966 and 1969 and their dietary intakes at entry were assessed using the 24-h dietary recall method. Standardized protocols were developed for data collection and processing. The daily servings of fruit and vegetables were of particular

interest and were categorized into quintiles.

After the baseline assessment, the subjects were followed up for 18 to 22 years and the incidence rates of stroke, cardiovascular disease, and cancer were tallied according to hospital admission records and communication with physicians and relatives. The cited research focused particularly on various types of stroke, namely, all stroke (including transient ischemic attack, TIA), completed stroke (both ischemic and hemorrhagic stroke), ischemic stroke, and hemorrhagic stroke. In addition to age, covariate measurements included energy and fat intake, serum total cholesterol, glucose intolerance, systolic blood pressure, the daily number of cigarettes smoked, body mass index (BMI in kg/m^2), time spent in different types of physical activities. Mantel-Haenszel method examined P values for trend of the 20-y age-adjusted cumulative incidence rates of each type of stroke by quintile of daily fruit and vegetable servings combined.

A significant decrease in risk with increasing quintile of fruit and vegetable intake was detected for all stroke (including TIA), completed stroke, and hemorrhagic stroke. Kaplan-Meier survival curves demonstrated a significant trend of protection ($P < 0.01$) against all stroke (including TIA) and completed stroke across quintiles of the intake. Cox proportional hazards analysis determined relative risks (RRs) and 95% confidence intervals (CIs) of each stroke type for each increment of three daily servings of fruit and vegetables after adjustment for age only and for all covariates, respectively. For each increment of three servings of fruit and vegetables, the age-adjusted RRs (95% CIs) were 0.78 (0.62-0.98) for all stroke, 0.74 (0.57-0.96) for completed stroke, 0.76 (0.57-1.02) for

ischemic stroke, and 0.49 (0.25-0.95) for hemorrhagic stroke. Allowance for all other covariates made little difference in the estimated protection effect against each type of stroke by increasing fruit and vegetable servings.

Several attributes of this study lend strength to its conclusion that "intake of fruits and vegetables appears to protect against the risk of stroke in men." A longitudinal approach provides insight into the temporal relationship between the exposure variable and outcome events. In addition, the research offered a detailed clinical assessment of each of the four stroke types and measured a large number of potentially confounding factors. Nonetheless, the precision of a single 24-h recall in estimating an individual's usual intake is open to question, and secular changes in dietary intake could not be examined. Joshipura et al. (1999) confirmed the protective effect of fruit and vegetables on ischemic stroke risk with his study in middle-aged men and women.

The citations discussed above were intended to exemplify the strength of existing epidemiological evidence, which suggests a protective effect of fruit and vegetable consumption on human health. For complete discussion of the subject please refer to several recently published reviews (American Institute of Cancer Research.1997; Block et al., 1992; Ness and Powles, 1997; Steinmetz and Potter, 1996).

Evidence from animal research

Epidemiological research bears several inherent limitations, such as recall bias and inability to fully identify and/or control confounders. Animal studies under controlled conditions are influenced far less by such limitations. Take the study by Rijnkels et al. (1997) as an example; the modulation of N-Methl-N'-Nitro-N-

Nitrosoguanidine (MNNG)-induced colorectal carcinogenesis was studied by feeding a vegetable-fruit mixture to rats maintained on a low- or a high-fat diet. In the study, 120 5-wk-old male Wistar rats were randomly divided into four groups of 30 animals each, receiving a semisynthetic diet without (Diets A and C) or with a vegetables-fruit mixture (19.5% wt/wt, Diets B and D). Meanwhile, Diets A and B contained 20 energy percent fat (low fat groups), whereas diets C and D contained 40% of energy as fat (high fat groups). Except for the contents of fat, vegetables-fruit mixture, and total energy, other aspects of the diet remained approximately the same across the experimental groups. The diets were assembled in such a way that their fatty acid composition and vegetable and fruit amounts (for Diets B and D) represented the mean consumption values in the Netherlands. Between the 4^{th} and 9^{th} weeks of the experiment, all rats were given weekly intrarectal instillation of 6 mg MNNG/kg body wt. Histopathological examinations of the colon and rectum were carried out to identify number, size, gross appearance, and location of tumors. At the end of the study, groups fed a vegetables-fruit mixture had significantly lower colorectal adenoma incidences than groups fed no such mixture. Also, the vegetables-fruit mixture appeared to counteract the carcinogenic effect of a high fat content by significantly lowering the colorectal adenocarcinoma incidence. It was concluded that a vegetables-fruit mixture not only significantly inhibits the carcinogenic effect of MNNG in rats, but it also interacts with dietary fat and counteracts its enhancing effect on the development of colorectal cancer.

Possible biochemical mechanisms for the protective effects

While it is utterly unquestionable that fruit and vegetables exert protection on

health, biochemical mechanisms that underlie their protective effects have yet to be fully elucidated. At present, the mainstream thoughts and research efforts are centered on antioxidants and phytochemicals contained in those foods. Antioxidants (eg, carotene, vitamins C and E) scavenge free radicals, which can cause cellular damage and lead to cancer, heart disease, and other diseases (Collins, 1999; Greenberg and Sporn, 1996). A voluminous body of research has examined the antioxidant content of fruits and vegetables as well as antioxidants and disease prevention. Recent research has identified a host of active nonnutritive substances from plants, known as phytochemicals. For example, detoxifiers are phytochemicals that destroy or eliminate toxic compounds introduced into the body or produced by the body; hormone regulators such as phytoestrogens which mimic the actions of natural estrogen, yet possess less potency; and cell regulators whose functions are speculated to be related to the inhibition of rampant cell growth (Craig, 1997). The field of phytochemicals is still in its early stage and its recent developments can be found elsewhere (Craig, 1997; King and Young, 1999; Krikorian, 1999).

It has been established that diet rich in fruits and vegetables increases plasma antioxidant capacity in humans. Cao et al. (1998) examined the impact of diets high in fruits and vegetables on human plasma antioxidant capacity with a crossover design. In all, 18 subjects aged 20-40 and 18 subjects age 60-80 with even numbers of men and women recruited. All subjects were in good health, were free of the use of alcohol and cigarettes, had not used antibiotics or vitamin/mineral supplements within 4 wk before the initiation of the study. Two 15-d residency periods were separated by a free-living