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RESEARCH PAPER

Fruit and Vegetable Intake Predicts Positive Affect

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Abstract Prior research suggests that fruit and vegetable intake predicts psychological well-being (WB) when controlled for demographic variables such as age, income and education. Using multiple-item measures and including additional diet and health variables as covariates, the current study assessed self-reported well-being in the past week and daily fruit and vegetable consumption over the past 4 weeks for 1270 university students. Mean positive affect increased linearly as a function of number of daily servings of fruits and vegetables; the pattern of this relationship did not differ significantly for males and females. This association remained statistically significant after controlling for demographic variables (age, sex, and parent education levels); other diet variables (consumption of sugar containing beverages, coffee or tea, and fat); and other health behaviors (exercise, sleep quality and smoking). Life satisfaction and negative affect were not significantly related to fruit and vegetable consumption. Analysis of single-item measures similar to those used in past large scale surveys yielded similar results. Possible reasons for the association of fruits and vegetable consumption with well-being are discussed.

Keywords Subjective well-being · Positive affect · Diet · Fruit · Vegetables

1 Introduction

Well-being research has focused primarily on positive traits (such as extraversion) and positive thoughts or social behaviors (such as optimism, hope, savoring, gratitude, or acts of kindness) as predictors of psychological well-being (Sheldon and Lyubomirsky 2006;

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Tkach and Lyubomirsky 2006). Lyubomirsky (2008) has also suggested that "taking care of your body" through exercise and meditation can increase well-being. Warner and Vroman (2011) examined the self-reported frequency of the 12 behaviors Lyubomirsky (2008) named as predictors of happiness (including acts of kindness, gratitude, and savoring, among others). Lyubomirsky included two health behaviors, exercise and meditation, in her list of happiness-inducing behaviors; Warner and Vroman (2011) added eating healthy foods. Correlations among the frequencies of happiness-inducing behaviors, and their ability to predict scores on happiness, were evaluated. The frequency of exercise and healthy eating did not correlate highly with the frequency of behaviors such as gratitude, kindness, and nurturing relationships; frequency of exercise and healthy eating significantly predicted happiness when controlling for other happiness-inducing behaviors. This result suggested that health behaviors may have a unique role in predicting happiness and perhaps other forms of well-being (WB).

Research on health behaviors as predictors of well-being has appeared mainly in journals outside positive psychology (e.g., journals in health psychology, sleep, exercise physiology, and social indicators) and has generally received little attention in reviews of positive psychology (e.g., Diener et al. 1999). What additional health behaviors beyond fruit and vegetable intake (FVI) might influence WB? Smoking (Stranges et al. 2014) and sleep quality (Kalmbach et al. 2014; McCrae et al. 2008; Steptoe et al. 2008) are reasonable candidates. Alcohol use, another potentially important variable, has complicated associations with WB; Tkach and Lyubomirsky (2006) pointed out that alcohol may be used to self-medicate for negative emotions, and this in turn can cause further negative emotions; however, in their data, alcohol use loaded on a factor that represented partying behavior, and more partying behavior predicted higher happiness scores. Evaluation of the social context of drinking is complex, and simple questions about frequency of amount of drinking probably will not provide enough information to understand how alcohol use is related to WB. In addition, other components of diet may be confounded with FVI and could be related to positive and/or negative affect. These include consumption of sugar-containing beverages and caffeine (Guo et al. 2014) and fat consumption (Corle et al. 2001).

Because there may be correlations among health behaviors, (e.g., people who eat a healthy diet may be less likely to smoke; people who consume a lot of fruits and vegetables may eat less fat), and because other behaviors in addition to FVI may influence well-being, research to evaluate whether fruit and vegetable consumption is related to well-being should control for other health behaviors. Few studies have evaluated whether controlling for other health behaviors changes the apparent importance of FVI a predictor. Studies that have controlled for health behaviors when evaluating FVI usually considered only smoking and exercise (e.g. Blanchflower et al. 2013). A more comprehensive assessment of FVI in the context of other health behaviors is needed.

1.1 Cross Sectional Surveys of FVI and WB

Most evidence about the association of FVI and WB has come from large-scale surveys (usually cross-sectional). Most of these surveys used single-item measures of FVI; analyses controlled for sex, age, income and education and sometimes smoking and exercise. All of the published studies we could find reported a statistically significant association between FVI and various measures of WB, usually life satisfaction. The association has been monotonic and often close to linear, with higher levels of WB associated with higher levels of FVI. Higher FVI sometimes also predicted lower scores for negative affect (NA) and

depression, but this was less consistent. Collectively these studies have included hundreds of thousands of participants from the UK (Blanchflower et al. 2013; Booker et al. 2014; Putz et al. 2011); Canada (Caligiuri et al. 2012; Lengyel et al. 2007; McMartin et al. 2013); Australia (Mujcic 2014); New Zealand (Carr et al. 2013); and samples from 21 countries categorized into three regions as follows: Western Europe and the USA (Belgium, England, France, Germany, Greece, Iceland, Ireland, Italy, Netherlands, Portugal, Spain, USA), Central and Eastern Europe (Bulgaria, Hungary, Poland, Romania, and Slovakia), and Pacific Asia (Japan, Korea, Taiwan, and Thailand). (Grant et al. 2009). The finding that higher FVI is associated with higher well-being scores has been consistent across different ways of measuring variables, different countries, and across different age groups including adolescents, adults, and the elderly.

Studies have differed in the way FVI is assessed. Usually the assessment is based on one or two questions about number of portions of fruits and/or vegetables typically consumed daily. Portion size was often not clearly defined. Grant et al. (2009) compared no FVI versus at least 1 serving per day (Grant et al. 2009); Blanchflower et al. (2013) included a wider range of 0–7+ servings per day. Most studies have treated fruit and vegetable consumption as a single variable; Ford et al. (2013) examined fruit and vegetable consumption separately. Two studies have reported statistically significant interactions between FVI and sex with a stronger association for women than men (Ford et al. 2013; Mujcic 2014). Some researchers have used linear regression to predict scores on outcomes such as a 0–10 rating of life satisfaction (LS) from FVI, while Blanchflower et al. (2013) used logistic regression to assess likelihood of being in the highest LS category (with predictor variables such as FVI dummy coded so that potential nonlinear associations could be detected). In most reported analyses, WB was highest for the highest level of FVI that was reported by participants; Mujcic (2014) reported optimum WB at 4–5 servings of fruits and vegetables per day.

Because of differences in measures of FVI and WB and in type of statistical analysis it is not easy to summarize effect sizes across studies. Blanchflower et al. (2013) reported that FVI was a better predictor of WB than smoking and about as predictive of WB as marital status. Grant et al. (2009) reported that among participants who were "dissatisfied" with life, only 36 % reported consuming at least 1 serving of fruits or vegetables per day, whereas in the group of "very satisfied people" 49 % reported consuming at least 1 serving per day. Lengyel et al. (2007) found that elderly men who consumed fruits or vegetables daily were 3 times as likely to report life satisfaction as excellent compared to those who rarely consumed fruits or vegetables. These differences seem large enough to be of practical interest.

To summarize, data from numerous large scale cross-sectional surveys suggest that FVI consistently predicts various WB indicators (and occasionally predict measures of negative outcomes such as negative affect or depression). The effect size for FVI may be reasonably large compared to effect sizes for other widely recognized predictors. Although results tend to be discussed as if FVI might cause WB, authors have clearly acknowledged that other explanations are possible. WB might influence FVI, or both WB and FVI might be caused by other variables. Bidirectional influence is also possible. At this early stage in research, data are not sufficient to distinguish among these, although some potential confounds (i.e., perhaps both WB and FVI are both influenced by or associated with education) seem unlikely to account for the association because FVI and WB are still significantly related when variables such as education are statistically controlled (Blanchflower et al. 2013).

1.2 Non-Experimental Daily Diary Studies of FVI and WB

Two short-term daily diary studies of FVI and WB have been done with college students (Conner et al. 2015; White et al. 2013). These studies provide information about between person and within person associations of FVI with WB and about time lagged correlations (with a time lag of one day). These did not involve manipulation of FVI and so they do not provide a basis for causal inference. White et al. (2013) found that FVI was predictive of next day positive affect, but that positive affect was not predictive of next day FVI. This suggested that FVI might be influencing positive affect. However, Conner et al. (2015) reported that FVI reported on one day did not predict positive affect the following day; they were able to replicate the finding of same-day association between FVI and PA.

1.3 Experimental Assessment of FVI and WB

Early experiments by Christensen (1993) and Spring et al. (1987) compared effects of a carbohydrate rich/protein poor meal to a protein rich/carbohydrate poor meal on WB; results suggested that a high carbohydrate meal might have a calming effect. These studies did not specifically examine fruit or vegetable consumption. Relatively few experiments have assessed whether manipulations of FVI might influence mood. Smith and Rogers (2014) randomly assigned participants to consume either a healthy snack (fruit) or an unhealthy snack (chocolate, crisps) for 10 days and reported that participants reported fewer symptoms of depression and other negative emotions after 10 days of fruit snacks; however, there was no control for possible placebo effects. There is a large ongoing school meal intervention program in Denmark designed to increase FVI (Andersen et al. 2014; Damsgaard et al. 2012). Measures of WB were included although that was not the primary focus of the study. Preliminary results (Andersen et al. 2014) suggest the program was effective in increasing vegetable but not fruit consumption (possibly because fruit consumption was fairly high at baseline). Studies similar in design could be done in future to evaluate possible causal effects of FVI on WB.

1.4 Possible Mechanisms for FVI Influence on WB: Short Versus Long Term

Several possible mechanisms through which foods might influence WB were suggested by Rooney et al. (2013). Many of these involve short-term processes (i.e., reactions that occur within minutes, hours, or days of food consumption). First, foods that are pleasant in taste and texture may promote pleasure or savoring that in turn increases positive mood, at least for a brief time. Second, people believe that some foods (such as fruits and vegetables) are particularly healthy, and that other foods (such as potato chips) are particularly unhealthy. These beliefs or expectations may give rise to feelings of virtue or self-efficacy after consuming 'good' foods, and feelings of guilt or lack of self-control after consuming 'bad' foods. These feelings may influence short-term mood. In addition, high FVI may predict more positive subjective evaluations of physical health (Sodergren et al. 2012). People may have specific beliefs about certain foods that might influence their mood responses to those foods (e.g., "sugar makes you hyper"); many of these beliefs are not supported by research (e.g., Christensen 1993), however, these expectations may give rise to placebo effects on mood in response to certain foods.

Consumption of fruits and vegetables is related to the intake and therefore availability of micronutrients (e.g., vitamins and minerals; Cappucio et al. 2003; Pincemail et al. 2011).

Micronutrient availability might influence WB over the long term (weeks, months, or years), although most of the evidence is about negative affect in relation to deficiencies rather than positive affect. McMartin et al. (2013) reported that high FVI is related to lower odds of depression. Of course, high FVI also has positive effects on long-term physical health outcomes (Oyebode et al. 2014; Wang et al. 2014), and physical health is related to WB.

The possible mechanisms reviewed above suggest ways in which higher FVI might be associated with more positive WB. It is also possible that prior mood could influence subsequent food choice. For example, negative affect may be associated with cravings for simple carbohydrates (Christensen and Pettijohn 2001). These mechanisms through which FVI and WB might be related are not mutually exclusive.

1.5 Questions in the Current Study

The current study extends previously reported research on the relationship between WB and FVI in three ways. First, well-being is assessed using multiple-item measures that have been validated and used extensively in positive psychology research: The satisfaction with life scale or LS (Diener et al. 1985) and the positive affect (PA) and negative affect (NA) scales based on the Positive and Negative Affect Schedule or PANAS (Watson et al. 1988). Multiple-item measures are also used for diet variables (diet screeners published by the National Cancer Institute), beverage consumption (the BEV-Q 15 scale, Hedrick et al. 2012), and exercise (the International Physical Activity Scale, Ekelund et al. 2006). Past surveys have generally included single-item measures for FVI (and for other health behaviors if these were included). We included single-item measures of life satisfaction and FVI, worded the same way as in the survey used by Blanchflower et al. (2013), so that we could compare results with single-versus multiple-item measures. Some past studies have included only a positive outcome variable such as life satisfaction; or only a negative outcome variable such as depression. Use of the three WB measures recommended by Diener and others (satisfaction with life, PA, and NA) provides information about both positive and negative outcomes.

Second, in contrast to prior research, we assess how WB differs across different amounts of FVI. Past studies have often reported odds ratios or percentages and those do not provide a simple description of the dose-response relationship. We also report more widely familiar effect size indexes (such as R^2 increment in regression).

Third, the current study goes beyond past research by including a wider range of control variables, particularly measures of other components of diet (fat, sugar and coffee or tea consumption) and other health behaviors (sleep quality and smoking). This provides preliminary exploratory information whether FVI has a unique predictive role in the context of other health behaviors that might also be related to WB.

The analysis plan was designed so that we could evaluate whether the association between FVI and measures of WB appears to be linear or curvilinear, and whether there appears to be an FVI × sex interaction.

Our eight research questions are as follows:

(1) Does each measure of WB (LS, PA and NA) differ significantly across levels of FVI? We predicted that, as in past research, FVI would predict LS and PA. Results from past research with NA have been inconsistent and so we did not make a prediction whether NA would covary with FVI.

(2) Do WB measures show a linear or curvilinear trend across levels of FVI? We expected a linear association. However, our analyses make it possible to assess possible non-linearity.
(3) Does FVI interact with sex as a predictor of WB? Studies of FVI have rarely shown an interaction of FVI and sex, and no plausible mechanism to explain such an interaction has been proposed. We did not expect an FVI × sex interaction but we included this in initial analyses.
(4) Is WB related to FVI when controlling for demographic and other diet variables? To our knowledge, none of the past studies have assessed whether controlling for other diet variables such as fat and sugar changes the apparent predictive importance of FVI. We did not make a prediction whether these control variables would change the statistical association between FVI and WB.
(5) What is the effect size for the association between FVI and WB when other diet variables (including consumption of fat, sugar, and caffeine) are statistically controlled? Past studies have often reported strength of association in terms of odds ratios or percentages of persons who are in the "highest life satisfaction" group. We report effect size in terms more familiar to most people in positive psychology, such as $R^2_{increment}$ in regression.
(6) Does FVI predict WB when additional health behaviors such as exercise, sleep quality, and smoking are statistically controlled? Because the possible mechanisms through which FVI might promote well-being differ from the ways in which exercise or sleep might promote well-being, we expected that FVI would predict WB even when these other health behaviors are statistically controlled.
(7) If fruit and vegetable consumption are used as separate predictors, is one a stronger predictor than the other? Given inconsistent results from prior research and no clear reason why fruits and vegetables might influence well-being through different mechanisms, we did not expect that either fruit or vegetable intake would be a stronger predictor of WB.
(8) Do the single-item measures used in past research show the same results as the new multiple-item measures? We expected that multiple-item measures might provide more reliable information; because unreliability of measurements tends to attenuate correlations, it seemed reasonable to expect that the predictive power of variables such as FVI would be better when using more reliable measures.

2 Method

2.1 Participants

The overall sample of 1270 participants was recruited through two departments at a public university in New England during the years 2013–2014. The 2013 sample consisted of 144 Nutrition students and 634 Psychology students; the 2014 sample included 492 Psychology majors. As compensation, Nutrition participants were entered into a lottery drawing for a $100 cash prize; Psychology participants received 1 h of credit toward a psychology course. More than 95 % of the students at this university are white/non-Hispanic. The sample included 391 male and 879 female students. Ages ranged from 18 to 25; students younger than 18 or older than age 25 were dropped from the study. For mother and father education, the modal categories were BA or BS (40 % of mothers and 35 % of fathers);

level of education ranged from high school to doctoral or professional degrees. Information about income in the family of origin was requested using an open ended question in 2013 and a rating scale for income group in 2014; for the income rating scale, 69 % of responses were missing. Because of missing data, income was not used in subsequent analyses. Only 14 % of participants reported smoking.

2.2 Procedures

Questions were presented as an online survey that required less than 1 h to complete. Participants read an informed consent page, completed the survey that included all measures listed below, and read a debriefing statement. Procedures were approved by the University IRB and the Psychology Department Review Committee.

2.3 Measures

2.3.1 Demographic Control Variables

Demographic control variables included sex, age, mother education, and father education.

2.3.2 Well-being

Well-being was assessed by the Satisfaction with Life Scale (LS) (Diener et al. 1985) and the positive affect (PA) and negative affect (NA) scales from the Watson et al. (1988) PANAS. These variables are believed to represent slightly different aspects of WB; life satisfaction is a somewhat more cognitive evaluation of life circumstances that is not limited to a recent time period while PA and NA are more emotional aspects of WB and these are usually assessed during limited time periods (during the past week in this study). In our sample, LS was strongly correlated with both PA, $r(1263) = .493$, $p < .001$, and with NA, $r(1263) = -.40$, $p < .001$). Correlations of this magnitude are typical in past research, even though these variables are conceptualized as distinguishable aspects of WB. The correlation between NA and PA was smaller, $r\ (1266) = -.229$, $p < .001$. The PANAS was designed to make the correlation between PA and NA relatively small so that effects of PA and NA can be distinguished. There is sometimes a tendency for variables to have somewhat higher correlations with each other when they are assessed using the same (rather than different) time frames. As in past research, LS, PA and NA had high internal consistency reliabilities (Cronbach's α of .91, .91, and .89 respectively).

2.3.3 FVI

FVI was assessed using public domain diet screening questionnaires published by the National Cancer Institute (NCI). The NCI All Day Fruit and Vegetable Screener is a public domain instrument available at http://appliedresearch.cancer.gov/diet/screeners/fruitveg/allday.pdf with scoring instructions at http://appliedresearch.cancer.gov/diet/screeners/fruitveg/scoring/ NCI screener items ask how many servings of fruit the person typically ate per day along with estimates of serving sizes. Other questions focused on serving frequency and serving size for several kinds of vegetables (such as salads, potatoes, vegetable soups, and beans). The standard time frame was used ("in the past month").

Items were scored following instructions on the NCI web site except that fruit juice (high in sugar) and French fries (high in fat) were excluded. Initial scores were continuous. In order to use ANOVA and to compare results directly with those from prior studies, the continuous scores were rounded to integer numbers of servings per day ranging from 0 to 8+ servings.

2.3.4 Fat Consumption

Fat consumption was assessed using the NCI Quick Food Scan (available at http://appliedresearch.cancer.gov/diet/screeners/fat/percent_energy.pdf) Diet scan questions include a variety of high fat foods such as hot dogs, cheese, and beef. We omitted the serving size questions. We obtained a measure of consumption of high fat foods (NCIfat). Unlike FVI, scores were not given in servings per day; the scores provided information about the range of different kinds of high fat foods consumed.

2.3.5 Consumption of Sugar-Containing Beverages, and of Coffee and Tea

Consumption of sugar-containing beverages, and of coffee and tea was assessed using the Bev-Q 15 (Hedrick et al. 2012). Sugarbev was the variable name for the approximate number of calories consumed daily through juice and non-diet soda. The mean for this variables was low because more than 500 persons reported that they never drank these beverages. Coffeeandtea was the approximate number of servings of coffee and tea per day. The BEV-Q 15 does not specify whether these were caffeinated or decaffeinated.

2.3.6 Sleep, Smoking, and Exercise

Sleep, smoking, and exercise measures were added to the survey during the 2014 data collection. There was a single-item rating of sleep quality (rated on a 5-point scale with 1 = very poor to 5 = excellent). There was a single question about smoking; as in most past research this variable was dummy coded (1 = smoker and 0 = nonsmoker). Exercise was assessed with the brief one-week version of the International Physical Activity Questionnaire (IPAQ) (Hallal and Victora 2004). The IPAQ is a public domain measure available at http://www.sdprc.net/wp-content/uploads/2012/06/IPAQ_SHORT_TELE_8-23-02.pdf Participants were asked how many days per week (and for how long) they engaged in vigorous physical activity, moderate physical activity, and walking; they also estimated how many hours per day they usually spend sitting. IPAQ scoring instructions specified treatment of outliers reported for minutes and hours (reported time less than 10 min was coded 0 and reported daily times greater than 180 min were recoded as 180). Number of days * minutes per day * energy expenditure for each level of activity was computed for vigorous and moderate activity and walking, and these products were summed to provide an estimate of energy expenditure in the past week, expressed as Metabolic Equivalents or METS. METS represent the energy expenditure for a specific activity (such as walking) divided by energy expenditure at rest; METSmin summarizes extra calorie expenditure (for the past week) based on the number of minutes spent walking and engaging in moderate and vigorous exercise.

Descriptive statistics for quantitative measures appear in Table 1.

Table 1 Descriptive statistics

	N	M	SD	Min	Max
FVI	1270	2.02	2.38	0	8+
Well being					
LS	1266	24.66	6.35	5	35
PA	1268	32.77	7.43	10	50
NA	1268	20.10	7.02	10	50
Demographic					
Age	1270	19.10	1.20	18	25
Mother education	1218	3.62	3.57	2	6
Father education	1196	3.57	1.15	2	6
Other diet					
NCI fat	1270	1.62	1.56	0	16
Sugar bev	1222	128.40	195.74	0	1404
Coffee and tea	1239	.36	.66	0	4
Other health					
Sleep quality	492	3.30	.85	1	5
IPAQ metsmin	492	4766.90	3502.40	0	16,524

FVI number of servings of fruits and vegetables per day from NCI All Day Screener

LS life satisfaction score, Diener et al. Satisfaction with life scale

PA and NA positive affect and negative affect from the Watson et al. (1988) PANAS

Mother education rated on scale from 2 = high school to 6 = PhD or professional degree

Father education

NCI fat consumption per day from NCI fat screener

Sugar bev calories per day from juice and soda

Coffee or tea servings of coffee or tea per day

Sleep quality rated from 1 = very poor quality to 5 = excellent

IPAQ metsmin typical energy expenditure per week combining vigorous

Moderate physical activity and walking, given in METS* minutes

3 Results

3.1 Preliminary Analyses

Scores for WB measures were reasonably normally distributed (as usual, low scores on LS and PA and high scores on NA were infrequent). Several control variables (coffeeandtea, sugarbev, NCIfat, and IPAQMETSmin) had positively skewed distributions. Log transformations did not make these distributions substantially more normal. To make the distribution shapes for these variables more nearly normal, based on visual examination of histograms, 3 % of the cases at the high end of the distribution for each variable were dropped, which equated to sugar beverage intake greater than 700 calories per day and NCIfat scores greater than 16 units per day).

Prior to other analyses, we evaluated whether data from nutrition and psychology students could reasonably be combined. MANOVA was performed to assess differences

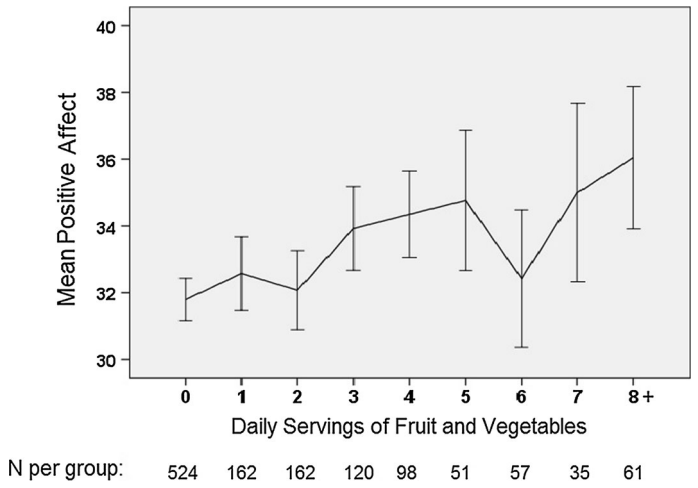

Fig. 1 Mean positive affect for groups by number of servings of fruits and vegetables per day (with 95 % Confidence Intervals)

across these two samples for all variables that were measured in both samples and included in subsequent analyses: FVI, PA, NA, LS, age, mother and father education, NCIfat, sugarbev, and coffeeandtea. The omnibus multivariate test was statistically significant, Wilks' $\Lambda = .981$, F (9, 1101) = 2.35, $p = .013$. This value of Wilks'Λ indicated that about 2 % of the variance for the set of means on these variables was related to nutrition versus psychology sample membership. Individual follow up tests indicated that nutrition students had significantly higher means on LS, PA, and FVI. Differences in means do not necessarily imply that interactions are present. However, subsequent analyses included sample membership and examined possible sample × FVI interaction. This does not test hypotheses of interest, but it helps to rule out the possibility that FVI might be related to WB in different ways for nutrition and psychology students.

The frequency distribution of number of servings of fruits and vegetables per day (FVI) for participants in our survey, ranging from 0 to 8 or more servings per day, appears in Fig. 1. Subsequent analyses compare mean WB scores across these 9 groups ranging from low to high consumption of fruits and vegetables.

3.2 Relationship between FVI and WB

To answer questions 1 2, 3, and 4, SPSS® GLM was used to evaluate how each WB variable differed across the 9 FVI groups. LS, PA and NA were examined as individual dependent variables in separate analyses. The GLM model was a 9 × 2 × 2 factorial (FVI × sex × sample). Covariates included age, mother and father education, and other diet variables (coffeeandtea, sugarbev, and NCIfat). Polynomial trend analysis and Tukey HSD post hoc comparisons were requested for the FVI factor. These analyses provided information about (1) which of the WB measures differed significantly across levels of FVI; (2) whether the pattern of change in WB across levels of FVI was linear or curvilinear; (3) whether the description of FVI/WB associations needs to be qualified by interactions with sex or sample; and (4) whether WB measures are still related to FVI when controlling for demographic and other diet variables.

When this GLM analysis was run using life satisfaction as the outcome variable, FVI was not a statistically significant predictor of LS, and interactions of sex and sample with FVI were not significant. Using the same GLM model to predict NA, the FVI main effect and interactions of FVI with sex and sample were again not statistically significant. Because of this no further analyses were done for either LS or NA.

On the other hand, using the same GLM factorial ANCOVA, PA was significantly predictable from FVI, $F(8, 1068) = 2.41$, $p = .014$. The sex × FVI and sample × FVI interactions were not significant. No other predictor in this analysis was significantly related to PA except for a main effect of sample membership with mean PA higher in the nutrition sample, $p = .02$. In the polynomial trend analysis, only linear trend was statistically significant, $p = .021$; higher order trends were not significant. A plot of mean PA across levels of FVI (number of servings of fruits and vegetables per day) appears in Fig. 1. Only the mean for the 6-serving group deviated notably from a linear pattern. Tukey HSD post hoc tests indicated that mean PA for the 6 serving group did not differ significantly from the means for neighboring groups. Adjustment for the covariates described above resulted in minimal change in this pattern.

3.3 Estimates of Effect Size with Statistical Control for Other Diet Variables

To answer question (5), hierarchical multiple regression analysis was used to examine the partition of variance among sets of predictors of PA. Use of linear regression seemed reasonable because previous our GLM analyses suggested that FVI was linearly predictive of PA and there was no evidence of significant interactions. Sample membership, sex, age, and mother and father education were added as predictors of PA on step 1; the R^2 increment on this step was .013 and this was statistically significant, $p = .001$. On step 2, diet variables were added (coffeeandtea, NCIfat, and sugarbev). There was not a significant increase in R^2 when these variables were added. On step 3, FVI was added. The increment in R^2 on this step was .023; this was statistically significant, $p < .001$. FVI uniquely predicted about 2 % of the variance in PA controlling for all the other predictors. Using Cohen's guidelines for effect size (Warner 2013) this is a small effect. For the final regression equation $R^2 = .20$, $p < .001$.

3.4 Does FVI Predict WB when Additional Health Behaviors such as Exercise, Sleep Quality, and Smoking are Statistically Controlled?

To answer question (6) we examined the subset of our data that included measures of these additional health behaviors (IPAQMETSmin, sleep quality, and smoking). Only some of the psychology students completed these additional measures, therefore the sample size for this analysis was 411. The first three steps of the hierarchical regression involved entry of the same predictors (except for sample membership which was now a constant) as in the preceding regression. For this subset of participants, neither the step 1 variables (sex, age, mother education, father education) nor the step 2 variables (NCIfat, sugarbev, coffeeandtea) provided a statistically significant increment in R^2 $\left(R^2_{inc}\text{step 1} = .017;\ R^2_{inc}\text{step 2} = .030\right)$. On step 3, the set of variables that included exercise, sleep quality and smoking had a significant R^2 increment ($R^2inc = .134, p < .001$). When FVI was added on step 4 there was a significant increment in explained variance $\left(R^2_{inc} = .021,\ p = .002 \text{ for FVI}\right)$. Together these health behaviors (exercise, sleep quality, smoking and FVI) accounted for 15.5 % of the variance in positive affect. This is a large effect size.

In the final regression equation, the only predictors other than FVI that had significant slopes were IPAQMETSmin ($\beta = .136$, $p = .004$); smoking, dummy coded 1 = yes and 0 = no ($\beta = -.142$, $p = .003$); and sleep quality ($\beta = .29$, $p < .001$). For FVI, $\beta = .148$, $p = .002$ (β values are standardized slopes).

3.5 Fruit and Vegetable Consumption as Separate Predictors

To answer question (7), correlations were obtained to examine daily fruit (NCIFRUIT) and vegetable (NCIVEGETABLE) consumption as separate predictors of PA. The correlation between NCIFRUIT and NCIVEGETABLE in the full sample was $r(1267) = .346$, $p < .001$. NCIFRUIT and NCIVEGETABLE each had statistically significant correlations with PA, $r(1267) = .151$, $p < .001$ and $r(1267) = .113$, $p < .001$, respectively. (Regression analyses to predict PA from regressions that included squared terms did not indicate significant non linearity for either variable.) The difference between these two correlations was not statistically significant, $z = 1.20$, $p = .11$.

3.6 Comparison of Single- Versus Multiple-Item Measures

To answer question (8), the regression analysis described in section 3.4 was repeated using single-item measures for fruit and vegetable consumption (Blanch FV), life satisfaction (BlanchLS) and happiness (Blanchhappy) that were worded exactly as described by Blanchflower et al. (2013). BlanchFV was a single question about daily fruit and vegetable consumption; BlanchLS was a rating of LS on a 10-point scale; and Blanchhappy was a rating of typical happy mood. As in section 3.4, hierarchical rsegression was performed entering sex, age, mother education and father education on step 1; NCIfat, sugarbev, and coffeeandtea on step 2; IPAQMETSmin, sleepquality, and smoking on step 4; and BlanchFV on the final step. In the first regression the dependent variable was BlanchLS; the R^2 increment for BlanchFV as a predictor of BlanchLS was not statistically significant, $R^2_{inc} = .006$, $p = .101$. In the second regression, Blanchhappy was the outcome variable; this was similar to the PA measure in the current study. In this regression, the $R^2_{increment}$ for BlanchFV added on the last step was .013, $p = .016$.

4 Discussion

This study significantly extends previous research on the association between FVI and WB. First, our results include a description of the dose-response function for PA across levels of FVI along with additional information about effect size. Second, our data suggest that it is important to differentiate among different types of WB outcomes when assessing psychological effects of FVI. Third, contrary to expectations, we did not find that use of multiple-item measures yielded a substantially stronger association between FVI and WB than single-item measures.

Question 1 was whether all three types of WB would be related to FVI. Among the three WB measures in our study, only PA was related to FVI. It was surprising that LS was not significantly related to FVI in our data because several past studies (e.g., Blanchflower et al. 2013; Caligiuri et al. 2012; and Grant et al. 2009; and Lengyel et al. 2007) reported a significant association. Inconsistent results for LS between our study and past surveys may be due to differences in sample composition, control variables, and statistical power.

Another possible reason why we found an association between PA and FVI in our study, but not between LS and FVI, was that our questions about PA and FVI referred to a different time period than our questions about LS. PA and FVI were assessed for the recent past (e.g., one week, one month) while LS did not have a limited time frame. The fact that LS was evaluated for a different time frame than FVI may have reduced its correlation with FVI in our sample. In other surveys, questions about LS and about FVI were evaluated for the same time frame (life in general rather than a limited recent past time period) and this may have contributed to higher correlations. Choice of time frame may be important.

The lack of a significant association between NA and FVI was less surprising because results of past studies have been inconsistent for NA and similar variables. Although LS and PA are negatively correlated with NA, it is possible PA and NA may be predicted by different variables (Warner and Rasco 2014). Negative affect may be something more than just a low level of positive affect; and different processes may be involved in promoting positive versus negative affect. Our results suggest that high FVI may be associated with higher positive affect; they provide no support for the possibility that low FVI is linked to low negative affect, although there is support for this in some past research. It is possible that low FVI is only related to clinical mood disorders such as depression when long-term diet quality is so poor that it leads to significant nutritional deficiencies; our sample probably did not include such extremes, whereas some past surveys that drew from more heterogeneous populations and vulnerable groups such as frail elders may have included these. While our results did not provide evidence of an effect of FVI on NA or on LS, they do not rule out these possibilities.

Our data did not suggest that the way FVI is related to PA differed for male versus female students. This was not surprising; there is not really a plausible mechanism to explain sex differences in response to FVI. The association of PA with FVI was linear in our data. Most previous studies have also found this association to be linear, with higher levels of WB occurring along with higher FVI. The statistically significant linear trend (with higher mean positive affect for higher levels of FVI) appeared to be the same whether rival explanatory variables (demographics and other diet components including sugar containing beverages, fat, and coffee and tea) were controlled or not. We do not know whether the coffee and tea consumed by students contained caffeine or not, and so our results do not directly evaluate possible effects of caffeine on positive affect. Future studies might assess caffeine consumption in a variety of forms including energy drinks.

The graphs of mean positive affect across levels of FVI did show a departure from linear trend such that students who reported 5 or 6 servings of fruit and vegetables per day reported lower PA than students who reported slightly lower or higher FVI. However, based on Tukey post hoc tests, the lower mean for this group was not significantly different from the means of neighboring groups. This FVI group had a relatively small N, particularly for male participants, and included a few low-end outliers. Sampling error is a plausible explanation why this group mean deviated somewhat from the linear trend pattern. Even with this anomaly, our results seem consistent with a linear dose-response relationship. This is the same as reported in most past studies, except that Mujcic (2014) suggested that highest WB might occur at a level of FVI a little lower than the maximum level included in their data, about 4–5 servings per day.

Most past research reports include effect size information in the form of odds ratios and percentages (e.g., for each 1 serving per day increase in fruits and vegetables, the increase in odds of being in the highest life satisfaction group, as in Blanchflower et al. 2013). We chose to describe the pattern of results in other ways. We could not find any past study in which results were graphed as a dose-response curve; this information is provided in

Fig. 1. Examining this graph makes it easy to answer questions such as, how large is the difference in positive affect between those who consume the lowest and highest numbers of servings of fruits and vegetables? Mean positive affect for the group with 0 FVI was 31.8; mean positive affect for the group with 8+ servings per day was 36.0. The standard deviation for positive affect was 7.4. If we focus only on these extreme groups and use these values to compute Cohen's d, $d = (36–31.8)/7.4 = .57$. A very large increase in fruit and vegetable consumption was associated with about a 4-point increase (or .57 standard deviation increase) in positive affect. Using Cohen's recommendations for evaluation of effect size, this would be considered a medium effect (Warner 2013). In addition, our analyses suggested that when controlling for rival explanatory variables, FVI uniquely predicted about 2 % of the variance in positive affect. Using Cohen's effect size standards, this is considered a small effect. Our effect sizes cannot easily be compared directly to those reported in past research. We did not do significance tests to compare the slopes of different predictor variables within our sample (e.g., was smoking significantly more or less predictive of WB than was FVI?) because there are numerous problems with this kind of comparison. The health behavior that appeared to be most predictive of WB in our data was sleep quality; this is consistent with substantial past research in sleep journals, and suggests that sleep quality (along with FVI) deserves more attention in positive psychology.

The use of multiple-item assessments for FVI and WB may not have added much value. Using single-item measures for FVI, LS, and happiness that were worded the same as in the Blanchflower et al. (2013) study of LS and FV, regression results were essentially the same as for the analyses that used multiple item measures. The regressions to predict single-item BlanchLS from BlanchFV, and to predict multiple-item LS from multiple-item FVI, both showed no significant association with FVI. For a multiple-item PA measure, and a conceptually similar-single item happy mood measure adapted from Blanchflower et al. fruit and vegetable consumption was a statistically significant predictor of positive affect when other variables were controlled. In other words, when we replaced our multiple-item measures with single-item measures and re-ran the analyses, our conclusions remained the same. In our sample, FVI significantly predicted positive affect (happiness) but not life satisfaction. It may be reasonable to use briefer measures of both WB and FVI in future studies. Elsewhere it has been suggested that a two-item assessment of FVI may be sufficient (Cappucio et al. 2003). Assessment of diet through self-report is difficult and it is not clear at this point what assessment method would work best to obtain information about fruit and vegetable consumption in future research on diet and WB.

Why did controlling for demographic variables make so little difference in our results? Compared to large scale surveys, members of our sample were fairly homogeneous with respect to age and parental education. We did not obtain enough information about income of family of origin to include this as a control variable. In effect, our study controlled for education and age by including only college students. Further statistical control for these variables, something that is necessary for samples drawn from the general population, was not useful in our study.

4.1 Issues to Consider in Future Research

The time frame included in questions to assess both well-being and diet may be important for two reasons. Pairs of variables that are assessed with the same time frame may tend to be more highly correlated than variables assessed for different time frames. Choice of time period for evaluation of well-being is also important because short- versus long-term

effects of foods might differ. Different mechanisms might explain short-term versus longer-term associations between FVI and WB (Rooney et al. 2013). Time periods of assessment need to be different for possible short- versus long-term mediating variables (such as savoring of recent meals as a way to improve mood short-term; and increases in levels of micronutrients that might lead to longer term improvements in well-being). The mechanisms through which diet could affect WB suggested by Rooney are not mutually exclusive, and several of them may need to be included in a more global theory about the ways that FVI might influence WB.

Time lags between observations in diary or longitudinal studies also need to be chosen thoughtfully. We need to ask questions such as: How long might it take for a person to feel mood improvement after eating one fruit snack, and how long would the positive effect last? How long does a person need to eat a high fruit and vegetable diet to change the micronutrient levels that might, in turn, influence mood?

In this study, four health behaviors in combination (sleep quality, exercise, smoking, and FVI) were each uniquely predictive of positive affect; sleep quality appeared to be the strongest predictor. This outcome is consistent with past research that documents the importance of these variables. Future research on the role of health behaviors as predictors of WB should include all of these behaviors; there may be other important health behaviors.

In the present non-experimental/cross-sectional study there are many possible explanations other than causality for the association between FVI and positive affect. For example, it is conceivable that some other variable (such as conscientiousness) influences both FVI and positive affect, and that the correlation between FVI and positive affect is due to this shared cause and not attributable to any direct connection between these variables. It is conceivable that positive affect influences FVI, although there is relatively little evidence to support that connection. It is also possible that there is bidirectional influence such that eating fruits and vegetables promotes positive affect and that in turn, positive affect promotes more consumption of fruits and vegetables.

The present study adds to a growing body of evidence that there may be a real association between FVI and positive affect. It could be worthwhile to conduct large scale experiments (similar to the study described by Andersen et al. 2014 and Damsgaard et al. 2012) to assess whether interventions to promote FVI might improve WB. Such research would help evaluate minimum dosage requirements and time course of effects. For example, how many servings of fruit and vegetables would a typical individual need to eat, over how long a period of time, to experience a noticeable improvement in mood?

This study leaves many questions unanswered. What variables might mediate potential effects of FVI on mood? These could include micronutrient availability, actual or self-perceived physical health; positive self-evaluations or expectations, savoring, and many other possible mechanisms, as suggested by Rooney et al. (2013). It has also been suggested that high consumption of fruits and vegetables (and perhaps little or no consumption of meat or other animal products) may be related to moral satisfaction and perhaps positive affect because high FVI is good for the environment and kills fewer animals (Rozin, personal communication, 2015). What is the direction of influence (if any) between FVI and WB, that is, does FVI predict future WB; does WB predict future FVI; or could there be mutual influence? Further research that includes measurement of FVI and WB at multiple time points will provide more information about temporal precedence. How important is FVI in an even larger context, when we consider not just other health behaviors, but also other happiness-inducing behaviors such as acts of kindness, gratitude, and nurturing social relationships?

Recent work in positive psychology has given relatively little attention to health behaviors other than exercise. The current study adds to a growing body of evidence that FVI (and also sleep quality and smoking) may have unique roles in the prediction of well-being. This has important theoretical implications, because it enlarges the set of happiness-inducing behaviors such as acts of kindness and gratitude to include additional behaviors that may have less obvious connections with well-being. There are also potential practical implications; it may be helpful to include information about mood benefits (as well as physical health benefits) in programs to improve diet. Health behaviors, including fruit and vegetable consumption, merit inclusion in further accounts of how behavior influences well-being.

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