

Article

Food Literacy and Dietary Intake in German Office Workers: A Longitudinal Intervention Study

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Abstract: Widespread patterns of poor dietary behavior are a key factor causing the increasing prevalence of chronic diseases around the world. Research provides initial insights into the potential of food literacy (FL) to empower individuals to improve their dietary behavior. Yet, studies on FL interventions in working adults are scarce. This study aimed to investigate the short- and long-term effects of a comprehensive 3-week workplace health promotion program (WHPP) on FL and dietary intake (DI) and to examine the association between FL and DI in a sample of 144 German office workers (30.0% female). Using two random intercept mixed linear regression models, we found significant strong improvements for both FL ($\beta = 0.52, p < .0001$) and DI ($\beta = 0.63, p < .0001$) after the WHPP when compared to baseline. Significant long-term improvements at 18 months were strong for FL ($\beta = 0.55, p < .0001$) and small for DI ($\beta = 0.10, p < .0001$). FL showed a significant moderate effect on DI across all measurement time points ($\beta = 0.24, p < .0001$). Our study fills a gap of long-term findings in the literature on FL interventions, offers insights into underlying mechanisms, and provides recommendations for effective WHPPs.

Keywords: health literacy; food literacy; dietary intake; nutrition; office workers; health promotion

1. Introduction

The increasing prevalence of chronic diseases is challenging societies and healthcare systems around the world. Lifestyle habits such as dietary behavior play a key role in the development of various types of chronic diseases, including obesity, diabetes mellitus, cardiovascular disease, hypertension, stroke, and some types of cancer [1]. In recent decades, Western populations have developed sociocultural habits and dietary patterns with detrimental health effects. Specifically, the prevalent eating behavior has shifted from the consumption of whole foods to highly processed, energy-dense, and nutrient-poor foods, also referred to as the nutrition transition [2–4]. Moreover, due to the abundance of convenience foods, many people no longer possess the necessary knowledge and skills to prepare healthy meals from whole food ingredients [3]. Together, these circumstances make it increasingly difficult for individuals to navigate the food environment in a healthy way [5]. Considering these extensive sociocultural nutrition-related threats to the health of individuals and societies, enabling people to make healthier food choices to prevent chronic disease is a key challenge in the modern world [1,6].

A large part of the population for which specific nutrition-related health threats have been investigated are office workers, who represent about 37% of all employees in Germany [7]. Specifically, pressure and stress at work, limited availability of healthy food, and social influences encouraging the consumption of unhealthy foods have been found to act as barriers to healthy eating in the office-based workplace [8]. Similar research in various workplace settings confirms these findings and presents further barriers to healthy eating in the workplace, such as lack of self-control and convenience, work

commitment, lack of time, and cost of food [9-12]. Together, these barriers shape a challenging environment for maintaining a healthy diet in the workplace.

In addition to these nutrition-related barriers to health-enhancing behaviors, office workers are highly exposed to sedentary behavior as a characteristic of their profession [13,14]. Together, nutrition and sedentary behavior influence the “energy gap”, which has been coined in research to describe the interaction of increased energy intake and decreased energy expenditure leading to increased rates of obesity and a range of non-communicable diseases [4,15,16].

Given this twofold burden of factors increasing their risk of chronic diseases, office workers need to be provided with knowledge and skills to improve their health behavior. Educating them on food and nutrition seems promising to accomplish this goal, since increased competencies can empower individuals to better navigate their food environment both inside and outside the workplace [17]. On the one hand, the resulting improved health behavior can be expected to increase employees’ health and well-being on the individual level [1]. On the other hand, these improvements can in turn be expected to also benefit a company by improving factors such as reduced sickness absences and increased work performance [18,19].

1.1. *Introducing Food Literacy*

Food literacy (FL) can be described as knowledge and skills related to nutrition [20]. The term has gained popularity among researchers in recent years, referring to a theoretical concept that can be addressed by interventions to affect health-related outcomes such as dietary behavior or, more specifically, dietary intake (DI) [4,21]. Early definitions of FL have been based on Nutbeam’s model of health literacy, which includes functional, interactive, and critical health literacy [22]. Functional FL refers to knowledge and skills regarding obtaining and understanding food-related information. Interactive FL comprises abilities to share such information in interactions between individuals, while critical FL focuses on the reflective analysis of the information obtained [23]. However, conceptualizations of FL have evolved over the years, and researchers have not reached a consensus yet [24,25]. The present study is set in the context of chronic disease prevention in office workers and thus places the focus on the relations between FL and health-enhancing eating behavior in the individual. In accordance with the view of Krause et al. [26], we define FL as “*competencies needed to maintain a healthy diet*” (p. 278).

1.2. *Current State of the Research on Food Literacy*

People commonly assume that educating individuals on nutrition will help them improve their dietary behavior [27]. However, possessing food skills does not necessarily translate into healthy dietary behavior directly [28,29] because dietary behavior is also influenced by other factors such as stress [30], sleep duration [31], or the barriers to healthy eating in the workplace mentioned above [8]. Considering these influences, it remains to be determined, to which extent FL is actually associated with the quality of DI despite everyday challenges and whether targeted interventions can improve FL and DI.

Overall, the existing evidence on the effectiveness of FL interventions must be interpreted with caution. Firstly, a lot of nutrition-related intervention research aimed at elements of FL does not use the term or concept. While these interventions do not discuss FL explicitly, their results and methodological discussions are still valuable for consideration in FL research due to the proximity of the underlying concepts. For example, reviews on the effectiveness of adult cooking interventions have concluded that diet-related knowledge and behavior can be improved [32-34]. However, there is agreement that the evidence is rather weak in quality and inconsistent regarding the results, with quality issues including small sample sizes, deficient evaluation tools, and lacking long-term follow-up data [32-34].

Secondly, many publications that refer to FL explicitly do not use a clear concept of the term, and publications that do use a clear concept have not reached a consensus yet regarding which one to use [24]. Thus, readers should bear in mind that, on the one hand, there may be publications that do not use the term FL but are still worth considering as background to FL research. On the other hand, there may be publications claiming to investigate FL that have little in common with the prevailing conceptualizations in FL research.

Regarding the research on FL explicitly, two conceptual reviews from 2017 and 2019 [23,35] delineate a healthy diet as a consequence of FL, implying a general association between the two variables. Support for this assumption can be found in a systematic review by Vaitkeviciute and Harris [36], who investigated the relationship between FL and DI in adolescents. Promising results regarding FL interventions were reported by Begley et al. [27], who found that a four-week nutrition education and cooking program targeting low to middle-income Australians improved FL and dietary behavior. Moreover, a four-week online FL program targeting Australian adults improved FL and increased fruit and vegetable consumption [37]. However, a study by Rees et al. [38] on participants of a seven-week cooking program showed increased cooking confidence but yielded no improvements in nutrition knowledge or healthy eating.

The controversy and limited evidence within this rather young field of research clearly reveal the need for further investigations on the effectiveness of interventions addressing FL to enhance dietary outcomes [26,35,39] and of the relation between FL and DI [6]. Given the health threats and barriers to healthy eating described above, this is especially the case for office workers [8].

When looking at interventions in the workplace, there are reports of workplace health promotion and wellness programs that include education on dietary behavior. Reviews and a meta-analysis evaluating worksite health promotion and wellness programs found evidence indicating that such programs can effectively improve DI, for example increasing fruit and vegetable intake and decreasing fat intake [40-43]. However, these reviews and the meta-analysis cover a wide range of work settings, types of programs, and study designs, and they mainly focus on dietary behavior but not on FL. To our knowledge, no previous study has determined the effect of a workplace health promotion program (WHPP) on FL and DI and examined the relation between FL and DI in office workers.

1.3. Aims of the Research Project

To address the gap in previous research as depicted above, we investigated the 1.5-year long-term effectiveness of a 3-week full-time WHPP regarding FL and DI as well as the relation between FL and DI in German office workers using four measurement time points. The corresponding research goals (RG) are:

RG1: To determine whether a 3-week WHPP will improve FL in German office workers and whether improvements will remain stable over the course of 1.5 years.

RG2: To determine whether a 3-week WHPP will improve DI in German office workers and whether improvements will remain stable over the course of 1.5 years.

RG3: To investigate the extent to which FL acts as a predictor of DI.

2. Methods

2.1. Participants

The sample investigated in this study consisted of 144 office workers for whom participation in a 3-week full-time WHPP had been assessed to be advisable based on a medical health check. Individuals with acute disease were not included in the study. Four hundred forty-six employees took part in the WHPP during the data collection period, of which 387 registered to participate in the study, and 328 met the inclusion criteria of

working in an office and not suffering from acute disease. Of these 328 individuals who filled in the questionnaire before the WHPP, 301 (92%) also answered it directly afterwards, 202 (62%) participated again after six months, and 146 (45%) also completed the final measurement time point after 18 months. From this sample of 146 participants, we excluded one due to too many missing responses and removed another as a multivariate outlier, resulting in a final sample of 144 (44%) participants. Table 1 displays the sociodemographic parameters of the participants who completed all measurement time points, both for the complete sample and divided by gender.

Table 1. Participants’ sociodemographic characteristics.

	Total (N = 144)	Men (n = 101)	Women (n = 43)
Age, M (SD)	50.0 (6.3)	50.5 (6.2)	48.6 (6.6)
Relationship status			
Relationship, n (%)	106 (73.6)	77 (76.2)	29 (67.4)
Single, n (%)	38 (26.4)	24 (23.8)	14 (32.6)
Education			
Tertiary, n (%)	87 (60.4)	75 (74.3)	12 (27.9)
Secondary, n (%)	54 (37.5)	26 (25.7)	28 (65.1)
Primary, n (%)	3 (2.1)	0 (0.0)	3 (7.0)

Notes. N = total sample; n = sub-sample; M = mean; SD = standard deviation; tertiary = college degree; secondary = vocational training; primary = high school qualification.

2.2. Intervention

The 3-week full-time WHPP took place in a wellness hotel and was implemented with groups of 60 employees each, including either male or female participants only. The WHPP was instructed by medical doctors, physical education teachers, psychologists, and dietitians. The concept covered all components of the information-motivation-behavior skills (IMB) model by Fisher et al. [44], which assumes that information on the behavior, as well as the motivation and behavioral skills to act, are the determinants of health-related behavior and thus the keys to changing it.

In the WHPP, information on nutrition and healthy eating was provided in the context of each meal, and in a 2-hour presentation by a dietitian. At the meals, information on the nutrient content of the main ingredients and their effects on the body were given with the menu, and pictures showed serving sizes and corresponding amounts of calories. The presentation covered macronutrients, including biochemical basics, their role in the body, health-related effects, content in different foods, and recommended consumption amounts. Several chronic diseases and their relationship with lifestyle habits were discussed, and topics with specific relevance for men and women, respectively, were addressed. The topics on diseases and well-being were expected to reinforce the participants’ motivation to apply their knowledge from the WHPP. The dietitian was available for personal consultation throughout the WHPP. In addition, guidance in reflecting, questioning, and improving individual habits was given, as well as tangible food recommendations including recipes and rules of thumb, and information about health-related supporting resources within the company. Key information, including presentation slides, nutrient tables, and recipes was handed to the participants after the WHPP for use at home. These aids were expected to improve behavioral skills and enable the participants to apply their knowledge and act on their motivation. Further details on the WHPP can be obtained from the corresponding author.

2.3. Measurement Procedures

We conducted this research project as part of a comprehensive evaluation of the occupational health management of a large engineering company in Germany.

Recommendations to participate in the WHPP were based on an occupational health check with the company's medical services, which evaluated the individual health status of the employees. Data were collected between April 2019 and July 2021. For this study, we used data from questionnaires covering sociodemographic details, FL, and DI. Participants gave informed consent before filling in the questionnaires. Assessments were conducted before the WHPP (T0), after completion of the WHPP (T1), as well as at 6- and 18-months follow-up (T2 and T3). In order to track individuals across measurement time points while ensuring data privacy, we asked them to generate a participant code that was based on four questions and designed to be easily reproducible by the participant. All study procedures complied with the German Federal Data Protection Act (BDSG), with the company's data privacy guidelines, and with the ethical standards of the 2013 Declaration of Helsinki [45]. The study received approval from the Ethics Committee of the School of Medicine of the Technical University of Munich (IRB number: 645/20 S-KH) and was pre-registered with the Open Science Framework ([Link](#)).

2.4. Measures

We evaluated FL using the Short Food Literacy Questionnaire (SFLQ) by Krause et al. [46]. As the SFLQ was originally validated with a Swiss sample, we adapted it slightly to fit German participants. The SFLQ is based on the theoretical framework of health literacy by Nutbeam [22] and assesses functional, interactive, and critical FL. It consists of 17 items (e.g., "When I have questions on healthy nutrition, I know where I can find information on this issue.", Cronbach's $\alpha = .81$, 95% CI = [0.78; 0.83]). The response format includes 4- and 5-point Likert scales and varies across the items. The overall score is formed by summing the responses for each item. It can take values between 0 and 52, with higher scores indicating more proficient FL [47].

Information on DI was collected using a German Food Frequency Questionnaire (FFQ) [48]. The FFQ enquires consumption frequencies of 24 food groups (e.g., "How often do you eat cheese?") with no indication of amounts. The response format is a 5-point Likert scale ranging from "1 – nearly every day" to "6 – never", and the questions refer to the previous four weeks. For each food group, a score is assigned, representing how closely the response matches the recommended consumption frequency according to the German Nutrition Society. The overall score is formed by summing the scores of 15 selected food groups. It can take values between 0 and 30, with higher values indicating consumption frequencies closer to the recommendations. The reliability and validity have been confirmed using a 7-day food diary in German adults [48].

2.5. Data Analysis

We conducted the statistical analysis in R (Version 4.2.0) [49]. The main data set included the participants who completed all four measurement time points and whose participant codes could be matched. This data set will be referred to as the per-protocol (PP) data set. We handled and reported missing data following the recommendations by Sterne et al. [50]. We imputed missing data using the mice package in R [51], applying predictive mean matching under the assumption that data were missing at random. 10% of the sociodemographic variables were missing, which had been neglected to collect for those individuals. For the FFQ and the SFLQ, the proportions of missing item responses were 2.6% and 6.2%, respectively, with no known reason for the absence of responses. We imputed missing sociodemographic variables based on both SFLQ and FFQ item responses at T0. For FL and DI, we imputed missing SFLQ item responses based on all SFLQ items and missing FFQ item responses based on all FFQ items, each including all measurement time points.

To examine whether missing values and drop-outs affected the results, we created a second data set containing the data of all individuals who completed at least T0 and T1, or T0, T2, and T3 with their participant codes assignable. This data set comprised a total

sample of $N = 303$, and it will be referred to as the intention-to-treat (ITT) data set. In the ITT data set, we imputed missing data as well, using predictive mean matching and assuming missingness at random. Sociodemographic variables were imputed from FFQ and SFLQ item responses at T0, using single imputation. Next, we added data from T1, T2, and T3 and calculated questionnaire sum scores for participants and measurement time points with no missing values at the item level. We imputed missing sum score values from existing sum score values and sociodemographic variables using multiple imputation with 5 data sets. This was the case for 17.1% of the SFLQ sum score values and for 18.0% of the FFQ sum score values. Trace plots and kernel densities indicated a good quality of the imputation. A descriptive comparison of the PP data set with one of the ITT data sets can be found in table A1 in appendix A.

Prior to the analysis, we removed multivariate outliers based on the recommendations by Tabachnick and Fidell [52]. That is, we calculated the Mahalanobis distance for each participant and used $p < .001$ as the cutoff to define multivariate outliers based on the resulting X^2 -distribution. This was the case for one individual. We analyzed all variables descriptively first, reporting mean and standard deviation, M (SD), for all variables. Pairwise comparisons of means based on paired Wilcoxon signed-rank tests [53] and adjusted using the Bonferroni method [54] are displayed in figure 1. Regression assumptions of linearity, normality, homoscedasticity, and independence of the residuals were met [55], and there was no considerable multicollinearity in the predictors. We set the significance level to $\alpha = .05$ and reported unstandardized as well as standardized regression coefficients to allow evaluating the effects in the development of FL and DI over the measurement time points. Effect sizes are classified as small ($\beta \approx .10$), moderate ($\beta \approx .30$), or strong ($\beta \approx .50$) [56], and each measurement time point is compared to T0. We evaluated the model fit following the recommendations by Nakagawa and Schielzeth [57], reporting the marginal R^2 , defined as the proportion of the variance explained by the fixed factors, and the conditional R^2 , defined as the proportion of the variance explained by the entire model including fixed and random effects.

We used two random intercept mixed linear regression models [58] to evaluate the research goals. Model 1 served to evaluate RG1 by investigating the development of FL over the four measurement time points. Model 2 served to evaluate RG2 by considering the development of DI over time while adjusting for FL and to evaluate RG3 by determining the overall association of FL and DI while adjusting for the measurement time points. Specifically, the following variables were included in the models:

Model 1: Measurement time point included as the predictor, FL as the outcome, age and gender as control variables, and the subject ID as a random factor.

Model 2: FL included as the predictor, DI as the outcome, age and gender and measurement time point as control variables, and the subject ID as a random factor.

3. Results

Based on the descriptive analysis, both FL and DI scores increased when comparing post- to pre-WHPP scores. FL scores increased from 33.0 (5.9) at T0 to 38.6 (4.6) at T1, subsequently increased further to 39.4 (5.1) at T2 and remained at about the same level with 38.8 (5.2) at T3. DI scores increased from 13.7 (3.3) at T0 to 19.3 (2.7) at T1 and subsequently settled to 15.4 (3.4) at T2 and 15.3 (3.4) at T3. Trajectories of FL and DI scores over the different measurement time points are displayed in figure 1, including significance levels for pairwise comparisons.

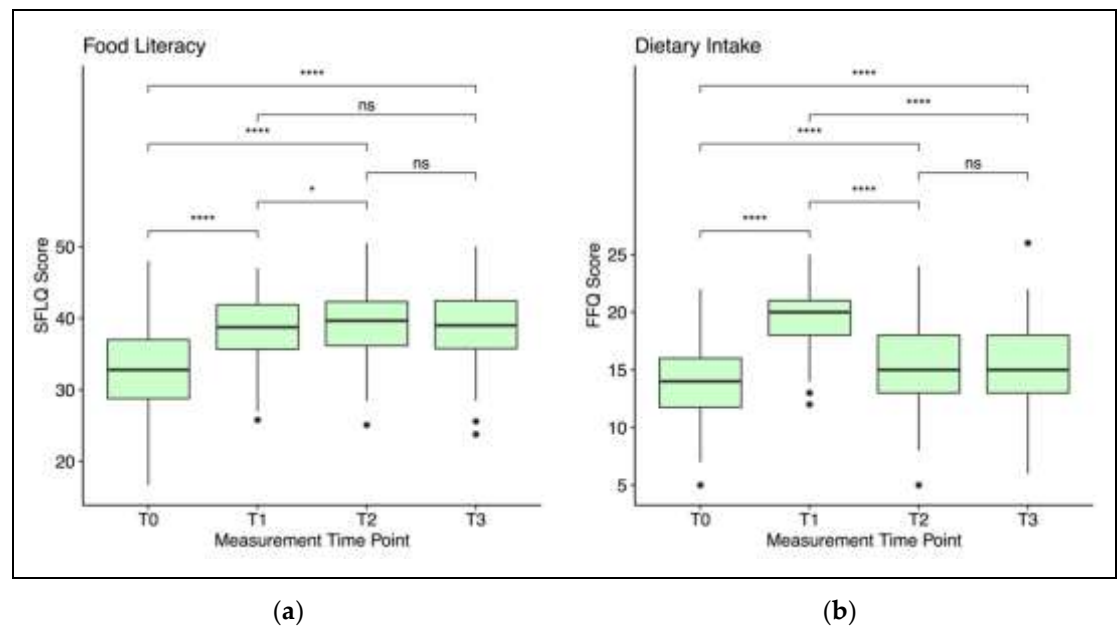


Figure 1. (a) shows standard box blots for FL scores measured by the SFLQ for each measurement time point. (b) shows standard box blots for DI scores measured by the FFQ for each measurement time point. Significance levels are denoted as ns: $p > .05$, *: $p \leq .05$, **: $p \leq .01$, ***: $p \leq .001$, ****: $p \leq .0001$.

Model 1 yielded a marginal R^2 of 26.9% and a conditional R^2 of 63.5%. Regarding RG1, which aimed to determine the effect of the intervention on FL, we found a strong increase in FL at T1 ($\beta = 0.52$, 95% CI = [0.45; 0.60], $p < .0001$) as well as at T2 ($\beta = 0.60$, 95% CI = [0.53; 0.68], $p < .0001$) and T3 ($\beta = 0.55$, 95% CI = [0.47; 0.62], $p < .0001$).

Model 2 yielded a marginal R^2 of 34.3% and a conditional R^2 of 64.0%. For RG2, which aimed to investigate the effect of the intervention on DI, we found a strong improvement in DI at T1 ($\beta = 0.63$, 95% CI = [0.55; 0.71], $p < .0001$), and small improvements at T2 ($\beta = 0.10$, 95% CI = [0.02; 0.18], $p < .05$) and T3 ($\beta = 0.10$, 95% CI = [0.02; 0.18], $p < .05$). With respect to RG3, which aimed to examine the capacity of FL as a predictor of DI, model 2 showed a moderate overall effect of FL on DI ($\beta = 0.24$, 95% CI = [0.15; 0.33], $p < .0001$).

Regression coefficients for the control variables and unstandardized regression coefficients for all variables are reported in table A2 (model 1) and table A3 (model 2) in appendix A. Comparing the results from the PP data set to the results from the ITT data set did not yield considerable differences, supporting the assumption that missing data did not influence the results of the analysis. A comparison of the model results for the two data sets can be found in table A2 (model 1) and table A3 (model 2) in appendix A.

4. Discussion

Empowering people to make healthier food choices to prevent chronic disease is a key challenge in the modern world [1,6]. The goal of this study was to evaluate whether a 3-week WHPP improved FL and DI in German office workers, and whether FL was a determinant of DI. Overall, we found long-term improvements for both FL and DI, and a moderate effect of FL on DI. Results are discussed for each RG individually.

4.1. Effects of the WHPP on Food Literacy

Our data show strong improvements in FL after the WHPP compared to before. These findings align with previous literature showing that nutrition education and cooking programs can improve nutrition-related skills and knowledge in various populations [32-34]. While previous research focusing explicitly on FL has already been promising

regarding the effectiveness of interventions on FL in diverse adult populations [27,37,38], our findings strengthen the evidence by focusing on office workers as a population with an increased risk of chronic disease [8]. Establishing FL as a variable that can be improved through health promotion interventions is vital because research on the closely related and more extensively studied concept of health literacy states that health literacy can be viewed as an asset that empowers individuals to exert greater control over their health [59].

Interestingly, our results show even further increases in FL at T2. We assume that the underlying mechanism may be the higher proficiency in food-related knowledge and skills after the intervention, which in turn equips individuals with a basis that makes accessing and understanding nutrition-related information easier. Support for this assumption can be found in research on health literacy. For example, a study found that individuals with higher levels of health literacy exhibit an increased use of the internet to seek health information compared with individuals with lower levels of health literacy [60]. Furthermore, the conceptualization of FL, which is based on the health literacy model by Nutbeam [22], holds that interactive FL comprises abilities to share nutrition-related information in interactions between individuals [23]. This concept suggests that FL enables individuals to improve their nutrition-related knowledge and skills further through social interactions. Thus, we assume that the FL gained from the intervention may have empowered our participants to subsequently further improve their FL, for example, by making use of other nutrition-related education offers within the company, by obtaining information from the internet, or by exchanging information with colleagues, friends, and families [23,60].

However, the idea that higher levels of FL facilitate further improvements also comes with a flipside because individuals with lower levels of FL tend to benefit less from interventions [59]. To attenuate this effect, interventions should be designed in accordance with the idea of precision prevention [61] by tailoring the content and methods to the competencies of the participants at baseline. This approach could be particularly valuable for WHPPs targeting diverse workforces since social status and educational level have been found to correlate with health literacy [62]. For example, groups could be built according to baseline FL levels, or interventions could be designed to offer suitable individualized teaching content and methods for participants on all levels.

Overall, our findings suggest that interventions can improve FL if designed and conducted carefully and might empower participants to continue expanding their knowledge and skills after the intervention.

4.2. Effects of the WHPP on Dietary Intake

Our data show strong improvements in DI after the WHPP in comparison to the baseline level, confirming the findings of previous studies evaluating nutrition-related effects of WHPPs [40-43]. Positive effects were still present in our study at both follow-up measurements. The significant long-term improvements are promising since they indicate long-term stability of positive changes in the participants' diets. These findings are valuable because it has been stated in previous literature on health behavior change that long-term effects of interventions are often either not reported [32,34], or in cases where follow-up measurements have been conducted, improvements were often not maintained by the participants [63,64].

When evaluating the trajectory of DI scores, each compared to T0, the strong increase at T1 in contrast with the small improvements at T2 and T3 is striking. This finding can most likely be attributed to the fact that the FFQ assesses DI retrospectively, thus DI scores at T1 mainly refer to the intervention period. While the participants were free to choose their food at all times, the WHPP in the wellness hotel provided a food environment that strongly supported healthy choices.

In general, health behavior is influenced by personal and environmental factors [64-66]. Personal factors such as knowledge, skills, and motivation in relation to eating a healthier diet or dealing with stress were addressed in the WHPP. However, the food

environment which participants are exposed to in their everyday life has not been fundamentally changed by the program. Thus, a main reason for the difference in DI scores between T1 and the follow-up measurements can be assumed to lie in the effects of the different food environments, with the WHPP setting enhancing healthy dietary behavior while the participants' everyday setting holds a range of barriers to healthy eating [8,67].

In association with this, it should be pointed out that our study was focused on the empowerment of individuals to adopt a healthy lifestyle, thus primarily covering personal factors of health behavior. However, readers should be aware that comprehensive WHPPs should also address and modify environmental factors to avoid placing the entire burden on the individual and achieve maximized long-term improvements [18,64,65]. Healthy food needs to be made available, easily affordable, and attractive in order to create health-enhancing food environments in which food-literate individuals can overcome remaining barriers and adopt healthy eating patterns [66].

All in all, our results on DI show that a WHPP focusing on personal factors of health behavior can be effective. However, long-term follow-up measurements are advisable to evaluate the true sustained effects regarding dietary behavior change.

4.3. Associations of Food Literacy with Dietary Intake

Our data show a significant moderate effect of FL on DI across all measurement time points. This finding suggests that knowledge and skills related to healthy eating do influence dietary behavior and provides support for delineating DI as a consequence of FL, as proposed by previous conceptual reviews [23,35]. A systematic review on the relationship between FL and DI in adolescents has found evidence for such a relationship as well, but the included studies have been reported to be limited in their validity due to mostly cross-sectional designs and the lack of validated measurement tools [36]. To our knowledge, similar findings in adult office workers have not been established yet. Our study contributes to strengthening the evidence on the relationship between FL and DI in adults.

Moreover, our study adds to the literature on workplace health promotion and wellness programs, which so far largely focuses on measuring dietary behavior as an outcome. By additionally investigating FL, we provide preliminary evidence for a potential mechanism explaining the effect of education-based WHPPs on DI. This mechanism strengthens the conceptualization of FL as an asset [59] to support the adoption of a healthier diet. That is, FL could help office workers to overcome barriers to healthy eating in the workplace [8] and to attenuate the energy gap [68] that results from sedentary work in combination with increased energy intake in order to achieve improved health outcomes [1]. We hope that our research will facilitate the inclusion of measures that address FL in the design of evidence-based health promotion interventions for adult office workers and encourage funders to invest in such interventions [69].

However, the effect of FL on DI that we found is moderate, suggesting that DI is affected by other factors as well. In fact, researchers propose an indirect relationship between FL and nutrition, which is influenced by factors such as individual values and food supply, as well as sociocultural factors and environmental aspects such as availability and affordability [17,29,66]. Motivation, which has not been measured in this study, is also considered essential for health-enhancing behavior in the IMB model by Fisher et al. [44]. Thus, FL can be regarded as one personal factor in a variety of personal and environmental variables that influence DI.

We conclude that interventions should not solely address FL but rather a combination of the influencing variables in order to achieve the most beneficial improvements in health-enhancing dietary behavior. That is, interventions should not only focus on teaching knowledge and skills but also incorporate key aspects such as promoting motivation, ideally based on psychological behavior change models like the IMB model [70].

4.4. Strengths and Limitations

We conducted this analysis using data from a comprehensive evaluation of a WHPP for employees of a large German engineering company. Strengths of our study include four measurement time points, including 6- and 18-months follow-up, allowing the evaluation of the long-term effectiveness of the WHPP, which has been pointed out to be lacking in other diet-related programs [32]. The use of both a PP analysis and an ITT analysis based on multiple imputation further increases the quality of our results [50].

Regarding measurement tools, the use of the SFLQ and the FFQ as validated questionnaires to measure FL and DI can be considered a strength [33]. Moreover, the SFLQ is based on a widely accepted theoretical framework of health literacy by Nutbeam [22] and was developed following a methodologically sound scientific procedure [46].

The 3-week full-time WHPP was a professionally designed intervention that seems well-suited for research on FL due to its high intensity, fairly long duration, and comprehensive concept covering all levels of the IMB model of health-related behavior change by Fisher et al. [44]. Moreover, with the intervention taking place in a wellness hotel, it was ensured to benefit from a positive implementation climate and a high engagement of the participants [71].

On the other hand, the design of our study also comes with some limitations. Since the data were collected in the context of the WHPP, there were no resources available to include a control or comparison group in the study design. Thus, we cannot evaluate whether our intervention was more effective compared to, for example, a shorter intervention using fewer resources. Additionally, the limitations of self-rating questionnaires need to be considered when interpreting our results, since respondents may not always have estimated and reported their knowledge, skills, and behaviors accurately [28,47]. Specifically, distortions like response-shift bias [72], recall bias, confirmation bias, and social desirability bias [73] may have influenced the results.

Readers should also be aware that the findings of this study are based on a sample of participants who were working in a large German engineering company, of which 72% were male, most were aged around 50, and had a higher educational background. Thus, inferences to other populations should be considered carefully.

Moreover, it should be clarified that in the context of the existing literature on FL, we apply a rather narrow definition of FL in order to match our study goals of investigating FL and DI in the context of chronic disease prevention in office workers. While this definition focuses on the individual, several researchers suggest extending the conceptualization. They argue that food-related attitudes, knowledge, and skills not only affect the person but also interact with the entire food system including social, cultural, economic, and environmental issues, and that these aspects should therefore be considered in definitions of FL [74-77]. A range of concepts of FL are being applied in the literature, thus readers should be aware of which concept each publication is based on [20].

4.5. Suggestions for Future Research

Firstly, considering the limitations of self-rating questionnaires, future studies could investigate whether the use of objective measures and the inclusion of a control group will yield results similar to our findings. Provided sufficient funds and resources are available, FL could be measured using task-based items [28], and DI could be measured using food records over several days, against which FFQs are frequently validated [78]. Moreover, the inclusion of comparison groups could strengthen the scientific evidence and provide insights into the respective effectiveness and efficacy of interventions that differ in characteristics such as duration, intensity, and level of customization within the framework of precision prevention.

A finding worth investigating in future studies is that the participants' FL increased even further after the end of the study. Randomized controlled trials should be conducted to verify our findings. Such trials could also provide further insights into whether the increased FL induced by the intervention is indeed the cause for further improvements in FL after the intervention or to what extent other mechanisms, such as an enhanced

awareness of the effects of nutrition on individual health or increased motivation play a role. Findings on these underlying mechanisms that empower individuals to continue improving their FL after an intervention could then provide information for the design of future FL interventions.

Regarding DI, our study focused on the basic relationship between FL and DI. Building upon these findings, it would also be interesting to investigate the relation of FL and DI with other factors that influence DI using structural equation modeling. For example, potential moderating effects of motivation [44], stress [30], sleep [31], or barriers to healthy eating in the workplace [8] on the relationship between FL and DI could be examined.

5. Conclusions

Our study indicates that health promotion programs can be effective with regard to FL and DI. We suggest that FL can be viewed as an asset, which on the one hand equips individuals with a basis that facilitates accessing, understanding, sharing, and further expanding food-related knowledge and skills. On the other hand, FL can also empower individuals to improve their dietary behavior, thus acting as a particularly valuable resource to support office workers in overcoming barriers to healthy eating in the workplace and attenuating the energy gap to improve a range of health outcomes. Considering our findings and the associated literature, we suggest that effective health promotion interventions should ideally be based on psychological behavior change models and cover both personal and environmental factors that influence dietary behavior according to scientific evidence in order to achieve beneficial health outcomes.

Supplementary Materials: None.

Author Contributions: Conceptualization, S.M. and S.B.; methodology, S.M. and S.B.; software, S.M., S.B.; validation, S.M., S.B.; formal analysis, S.M.; investigation, S.M.; resources, S.M., S.B., F.M.; data curation, S.M.; writing—original draft preparation, S.M.; writing—review and editing, S.M., S.B., F.M.; visualization, S.M.; supervision, S.B. and F.M.; project administration, S.B.; funding acquisition, F.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Siemens AG, grant no. (1601789).

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of the Institute of Medicine of the Technical University of Munich (645/20, November 2020).

Informed Consent Statement: Written informed consent was obtained from all participants involved in the study.

Data Availability Statement: The datasets generated and analyzed during the study are not publicly available owing to patient confidentiality but are available in a highly anonymized form from the corresponding author on reasonable request.

Acknowledgments: We thank Mourad Zoubir for proofreading the manuscript.

Conflicts of Interest: The funders had no role in the design, data collection, analyses, data interpretation, and writing of this manuscript, nor do they have any role in the decision to publish the results. The funding has no relationship with the design, data collection, analyses, data interpretation, and writing of this manuscript because the general aim of the funding was to evaluate parts of the WHPPs of Siemens AG. The authors declare no conflict of interest.

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Appendix A

Table A1. Descriptive comparison of per-protocol and intention-to-treat data set.

Variable	Per-protocol (N = 144)	Intention-to-treat (N = 303)
Age, M (SD)	50.0 (6.3)	50.4 (6.3)
Gender		
Female, n (%)	43 (29.9)	83 (27.4)
Male, n (%)	101 (70.1)	220 (72.6)
Relationship status		
Relationship, n (%)	106 (73.6)	220 (72.6)
Single, n (%)	38 (26.4)	83 (27.4)
Education		
Tertiary, n (%)	87 (60.4)	186 (61.4)
Secondary, n (%)	54 (37.5)	108 (35.6)
Primary, n (%)	3 (2.1)	13 (4.3)
Food Literacy, M (SD)	37.4 (5.8)	37.3 (6.0)
T0, M (SD)	33.0 (5.9)	32.6 (6.3)
T1, M (SD)	38.6 (4.6)	38.4 (4.6)
T2, M (SD)	39.4 (5.1)	39.4 (5.0)
T3, M (SD)	38.8 (5.2)	38.7 (5.4)
Dietary Intake, M (SD)	15.9 (3.8)	15.5 (3.3)
T0, M (SD)	13.7 (3.3)	13.6 (8.4)
T1, M (SD)	19.3 (2.7)	18.5 (2.8)
T2, M (SD)	15.4 (3.4)	14.9 (2.7)
T3, M (SD)	15.3 (3.4)	14.7 (3.1)

Notes. N = total sample; n = sub-sample; M = mean; SD = standard deviation; tertiary = college degree; secondary = vocational training; primary = high school qualification.

Table A2. Regression coefficients for model 1, with FL as outcome.

Variable	Per-protocol (N = 144)	Intention-to-treat (N = 303)
unstandardized		
Age, β [CI]	0.02 [-0.08; 0.12]	-0.01 [-0.8; 0.05]
Gender male, β [CI]	-3.45 [-4.87; -2.03]	-2.50 [-3.56; -1.43]
T1, β [CI]	5.59 [4.78; 6.41]	5.76 [5.05; 6.46]
T2, β [CI]	6.42 [5.61; 7.24]	6.71 [5.87; 7.54]
T3, β [CI]	5.85 [5.03; 6.66]	5.90 [5.00; 6.79]
standardized		
Age, β [CI]	0.04 [-0.15; 0.22]	-0.04 [-0.19; 0.11]
Gender male, β [CI]	-0.45 [-0.63; -0.26]	-0.40 [-0.55; -0.25]
T1, β [CI]	0.52 [0.45; 0.60]	0.47 [0.49; 0.60]
T2, β [CI]	0.60 [0.53; 0.68]	0.55 [0.49; 0.60]
T3, β [CI]	0.55 [0.47; 0.62]	0.48 [0.43; 0.54]

Notes. N = total sample; β = regression coefficient; CI = confidence interval.

Table A3. Regression coefficients for model 2, with DI as outcome.

Variable	Per-protocol (N = 144)	Intention-to-treat (N = 303)
unstandardized		
Age, β [CI]	0.02 [-0.04; 0.08]	0.04 [0.01; 0.07]
Gender male, β [CI]	-0.55 [-1.43; 0.33]	0.08 [-0.52; 0.68]
T1, β [CI]	4.89 [4.28; 5.50]	4.41 [3.92; 4.90]
T2, β [CI]	0.79 [0.16; 1.42]	0.74 [0.14; 1.35]
T3, β [CI]	0.77 [0.15; 1.38]	0.61 [0.12; 1.33]

FL, β [CI]	0.14 [0.09; 0.19]	0.09 [0.03; 0.14]
standardized		
Age, β [CI]	0.07 [-0.15; 0.29]	0.31 [0.07; 0.56]
Gender male, β [CI]	-0.14 [-0.36; 0.09]	-0.04 [-0.22; 0.29]
T1, β [CI]	0.63 [0.55; 0.71]	0.60 [0.54; 0.65]
T2, β [CI]	0.10 [0.02; 0.81]	0.10 [0.04; 0.16]
T3, β [CI]	0.10 [0.02; 0.81]	0.08 [0.03; 0.14]
FL, β [CI]	0.24 [0.15; 0.33]	0.16 [0.11; 0.22]

Notes. N = total sample; β = regression coefficient; CI = confidence interval.

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