

A randomized experiment to examine unintended consequences of dietary supplement use among daily smokers: taking supplements reduces self-regulation of smoking

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ABSTRACT

Aims We examined whether smokers' use of dietary supplements (e.g. vitamin C, multi-vitamins) induces illusory invulnerability that in turn disinhibits smoking. Such supplement use may be perceived as conferring health credentials. **Design** A single-factor (credentials: with or without) between-subjects design was employed. Smokers were assigned randomly to take either a known placebo pill or a dietary supplement (in fact, the same placebo) in an ostensible health-food test. **Setting** Laboratory at Kaohsiung Medical University, Taiwan. **Participants** Study 1 involved of a student sample consisting of 74 daily smokers, whereas study 2 involved a community sample consisting of 80 daily smokers. **Measurements** In Study 1, participants reported their perceived invulnerability following the manipulation. In study 2, pre- and post-test measures of invulnerability were administered, and attitudes towards dietary supplements were assessed prior to the manipulation. In both studies, the dependent measure was the number of cigarettes smoked during completion of an unrelated survey. **Findings** Participants who believed that they were taking a dietary supplement smoked more cigarettes than did controls. Study 1 found support for the role of perceived invulnerability as a mechanism underlying this effect. Study 2 demonstrated the moderating effect played by attitudes towards dietary supplements: a more positive attitude towards supplements increased susceptibility to licensing effects. **Conclusions** Dietary supplement use may create illusory invulnerability, reducing the self-regulation of smoking. Reminding health-conscious smokers that multi-vitamins do not prevent cancer may help such smokers to control their smoking and encourage them to stop.

Keywords Attitudes towards dietary supplements, invulnerability, licensing, smoking.

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INTRODUCTION

Epidemiological and experimental evidence consistently supports a causal relationship between cigarette smoking (CS) and the development of lung cancer [1]. Although fruit and vegetable consumption is associated with a lower incidence of lung cancer [2], supplemental vitamins for chemoprevention have also received considerable interest. This is because dietary habits are difficult to change [3]. Data from the 2003–06 National Health and Nutrition Examination Survey, a nationally representative, cross-sectional survey of US health and nutrition,

indicated that approximately 50% of the US population and 70% of adults more than 71 years of age use dietary supplements [4], and a majority believe that such supplements are 'good for health and well-being' [5]. Given the widespread use of supplements, researchers have focused considerable attention on the link between dietary vitamin C and CS-associated diseases. There is some evidence that vitamin supplementation has physiological effects relevant to cancer prevention [6], but epidemiological studies suggest that higher consumption of vitamin C, vitamin E and folate is not associated with a lower incidence of lung cancer [7,8]. Furthermore,

randomized trials show that vitamin supplements do not prevent cancer and may even be associated with an increased risk of cancer [9,10].

Vitamin supplements may, however, be associated with adverse consequences if people believe that taking them reduces their risk of cancer, and this allows them to engage in other risky behaviour. Known as the 'licensing effect', which refers to how people, given solid evidence that they possess some valued trait, gain licence to act in ways counterproductive to maintaining that trait. For example, Monin & Miller [11] found that actions supporting gender equality licensed subsequent behaviours reflective of sex discrimination. Similarly, Effron *et al.* [12] showed that the opportunity to endorse Barack Obama subsequently rendered individuals more likely to favour Caucasian over African American individuals. Additionally, Mazar & Zhong [13] found that people act less altruistically and are more likely to cheat and steal after purchasing green products than after purchasing conventional products. Previous studies on licensing effects have focused largely upon the moral domain. However, Chiou *et al.* [14] showed that participants taking dietary supplements walked less than the control group, even after an explicit reminder about the health benefits of walking. In the present research, we tested if these licensing effects are still held true in cigarette consumption among daily smokers.

As argued from the perspective of psychological licence [11–14], people may be motivated strongly to engage in health-protective behaviours if their identity as 'healthy' is at stake. For example, engagement in activities that pose health risks should motivate engagement in acts that restore health. However, engagement in actions that are perceived as improving physical health may also compensate for perceptions of an unhealthy self, implying that participation in health-protective actions can provide psychological licence for participation in subsequent risky behaviours. Hence, we predict that dietary supplement use will boost perceived invulnerability and health-related licence and thereby reduce self-regulation of subsequent smoking.

We conducted two experiments to determine whether perceived supplement use would licence increased cigarette consumption. In line with psychological licence, health credentials may be established by engaging in health-protective behaviours, e.g. dietary supplementation in this research. We examined the effect of health credentials related to supplement use on subsequent levels of smoking. We also examined the hypothetical mechanism underlying licensing effects (i.e. perceived invulnerability; study 1) and tested a moderator of this effect (i.e. attitudes towards dietary supplements; study 2).

STUDY 1

Methods

Participants

The formal sample in this experiment consisted of 74 undergraduate daily smokers [females = 20, males = 54, aged 18–25 years; mean age = 20.54, standard deviation (SD) = 1.36] who were recruited through campus posters, flyers or word of mouth. The candidate participants ($n = 89$) were screened through face-to-face interviews to ensure that they met the following study criteria: no history of allergies to dietary supplements, no current psychopathology or developmental disability, no recent attempt to quit or reduce their smoking and smoking at least five cigarettes per day for the past year. We asked participants not to take any dietary supplements on the day of study participation. Participants were also told to bring their usual brand and type of cigarettes to the study.

Setting

The laboratory consisted of two rooms connected by a small shaft that permitted the experimenter to communicate with the participant. In the smoking room, a chair, table, ashtray, lighter and respiratory tube were present. The respiratory tube was connected to a ventilator in the ceiling. Experimental sessions were conducted with a half-hour break between participants to minimize the salience of smoking by previous occupants in the room.

Procedures

Upon arrival, participants were informed that they were going to engage in several unrelated tasks. All participants provided written consent. They reported demographic information and regular daily use, if any, of dietary supplements. They also rated nicotine dependence on the seven-item modified Fagerström Tolerance Questionnaire (mFTQ). Adequate reliability and validity of the mFTQ has been demonstrated [15]. The sum of the seven mFTQ items was used (range: 0–9).

The participants were then assigned randomly to one condition of a single-factor (credentials: with versus without) between-subjects design. We employed a block-randomization method to balance gender proportions between the two study conditions. Participants were asked initially to help a faculty member in the department of biological sciences with a health-food test to be used in a future randomized, placebo-controlled study. They were asked to take either a vitamin C supplement (i.e. the credentialled group) or a placebo pill (i.e. the control group) and then to rate the perceived attributes of the pill they had just taken (e.g. size, shape, colour, texture). Unbeknown to the participants, all received placebo pills. Later,

participants were asked to complete an ostensibly unrelated questionnaire about personality. The experimenter told each participant: 'This survey will take you about one hour to finish. Therefore, you are allowed to smoke if you want'. Each participant was led to a smoking room to complete the survey. The time (in minutes) for completing this survey was recorded. At the end of the experiment, participants received a funnel debriefing in which the manipulation effectiveness and their ability to guess the hypothesis were checked. All participants recognized the kind of pills they took. None expressed any suspicion about the credentials manipulation or the dependent measures.

Measurements

This experiment also embedded a measure of our proposed mediator, perceived invulnerability, in the personality questionnaire. Specifically, we employed the nine-item General Invulnerability (GI) subscale of the Adolescent Invulnerability Scale [16], which has demonstrated good construct validity in adolescent community samples [17]. Sample GI questions include the following: 'Nothing can harm me'; 'There are times when I think I am indestructible'; and 'Special problems, such as getting an illness or disease, are not likely to happen to me'. Respondents indicated their level of agreement with these items on a five-point scale (0 = strongly disagree, 4 = strongly agree). Higher scores suggest greater perceived invulnerability. The responses of participants to these items showed high consistency ($\alpha = 0.85$), and

their scores across the items were averaged. The dependent variable was the number of cigarettes smoked during the survey, which was measured using the number of cigarette butts left in the ashtray.

Results and discussion

Level of smoking

Smoking was not associated with gender (female: 65%, 13 of 20, male: 80%, 43 of 54; $\chi^2_{(1)} = 1.70$, $P = 0.193$, $\phi = 0.151$). Therefore, male and female data were collapsed for subsequent analyses. We employed binary logistic regression to examine whether smoking (1 = smoking, 0 = smoke-free) was associated with the credential manipulation (1 = credentialled, 0 = control), treating number of daily supplements taken (mean = 0.68, SD = 0.62) and nicotine dependence (mean = 4.45, SD = 1.26) as control variables. As predicted, participants in the credentialled group were more likely to smoke (89%) than were the control participants (62%), odds ratio = 1.44, 95% confidence interval: 1.35–1.54, Wald = 5.75, $P = 0.016$, Cox & Snell $R^2 = 0.112$ (Table 1).

Number of cigarettes smoked

Participants in the two study conditions did not differ in time taken to complete the survey (Table 1), $t_{72} = 0.55$, $P = 0.587$. With respect to the licensing effect of vitamin C intake, a pattern emerged in terms of the number of cigarettes smoked (mean = 1.76, SD = 1.39).

Table 1 Participant demographics, descriptive statistics for the measures in study 1 and the effect of supplement use on perceived invulnerability and smoking.

	Credentialled condition		Control condition	
	<i>n</i> = 37	%	<i>n</i> = 37	%
Undergraduate sample				
Gender				
Male	20	50.0	20	50.0
Female	17	50.0	17	50.0
Supplement users	18	48.6	19	51.3
	<i>Mean</i>	<i>95% CI</i>	<i>Mean</i>	<i>95% CI</i>
Number of daily supplements taken	0.54	(0.34–0.74)	0.51	(0.29–0.73)
Nicotine dependence ^a	4.22	(3.83–4.61)	4.68	(4.27–5.09)
Survey completion time (minutes) ^b	40.14	(37.44–42.84)	39.54	(37.97–41.11)
Perceived invulnerability ^{c,d}	2.49	(2.27–2.71)	1.74	(1.49–1.99)
Proportion of refraining from smoking ^e	0.11	(0.01–0.21)	0.38	(0.22–0.54)
Number of cigarettes smoked ^f	2.35	(2.05–2.65)	1.23	(0.94–1.52)

^aScores on the nicotine dependence scale ranged from 0 to 9. ^bSurvey completion time did not differ between conditions. ^cScores on the perceived invulnerability scale ranged from 0 to 4. ^{d,e,f}Mean differences indicated that participants who received the vitamin C use manipulation (the credentialled condition) felt greater invulnerability, showed less likelihood of refraining from smoking, and smoked more cigarettes in an ostensible survey than did the control participants. CI: confidence interval.

Participants in the credentialled group (mean = 2.35) smoked more cigarettes than controls (mean = 1.23) when the number of daily supplements taken and nicotine dependence were controlled, $F_{(1, 68)} = 8.23$, $P = 0.005$, $\eta_p^2 = 0.108$ (Table 1). Additionally, the effect of credentialling on cigarettes smoked was independent of gender, $F_{(1, 68)} = 2.46$, $P = 0.122$, $\eta_p^2 = 0.035$.

Mediation

Participants who took vitamin C felt greater invulnerability (mean = 2.49) than did controls (mean = 1.74) when the number of daily supplements taken and nicotine dependence were controlled, $F_{(1, 70)} = 19.04$, $P < 0.001$, $\eta_p^2 = 0.213$ (Table 1). To examine whether perceived invulnerability mediated the effect of dietary supplement use on the number of cigarettes smoked, we followed the procedures recommended by Baron & Kenny [18]. Using the number of cigarettes smoked as the dependent variable, we created a dummy variable for our manipulation (1 = the credentialled condition) and treated number of daily supplements taken and nicotine dependence as control variables. As expected, the effect of taking vitamin C on the number of cigarettes smoked was no longer significant (from $\beta = 0.411$, $P = 0.004$ to $\beta = 0.093$, $P = 0.33$) when perceived invulnerability (mean = 2.12, SD = 0.82) was included in the equation, and perceived invulnerability was a significant predictor of the number of cigarettes smoked ($\beta = 0.719$, $t = 8.66$, $P < 0.001$). The inclusion of perceived invulnerability increased the variance explained significantly (by 37%, from $R^2 = 0.16$ to $R^2 = 0.53$; $F_{(1, 69)} = 52.16$, $P < 0.001$); the Sobel test was significant, $Z = 3.84$, $P < 0.001$, indicating that perceived invulnerability mediated the licensing effect of vitamin C intake on the number of cigarettes smoked (see Fig. 1).

Dietary supplementation with vitamin C seemed to licence participants to engage in risky health behaviours, as reflected by their subsequently smoking more cigarettes. These results suggest that the dietary supplement use may increase perceived invulnerability and thereby licence subsequent self-indulgence.

Furthermore, if dietary supplement use licences health-risk behaviours, then such use should have an

especially strong effect on smokers who have positive attitudes towards supplements. We tested this prediction in study 2 by including a measure of attitudes towards supplements before the manipulation of perceived supplement use. We predicted that smokers with more positive attitudes towards supplements would take greater advantage of perceived credentials. Further, study 1 is limited because perceived invulnerability was not measured before the intervention. In study 2, perceived invulnerability was measured both before and after the intervention. Pre-post changes in perceived invulnerability would show more directly the impact of the manipulation and help to shed light on how easily licensing effects may be influenced.

STUDY 2

To increase the generalizability of our findings, study 2 included three alterations. First, we recruited participants from the larger community, using a subject pool drawn from a civic health study in Kaohsiung city (the largest city in southern Taiwan). That study was administered through the College of Health Sciences at Kaohsiung Medical University. Secondly, we told the participants in the credentialled condition that they were taking a multi-vitamin pill. Thirdly, we investigated the moderating role of attitudes towards supplements on the licensing effect.

Methods

Participants

The study sample consisted of 80 participants ranging in age from 19 to 58 years (mean = 30.33 years, SD = 8.53; females = 26, males = 54) who were not attempting to quit or cut down on smoking. Nine candidate participants who did not meet the study criteria mentioned in study 1 were screened out.

Measurement of attitudes towards dietary supplements

We drew from Dreezens *et al.* [19] to assess participants' attitudes towards dietary supplements. Participants were asked to respond to the question: 'What do you generally

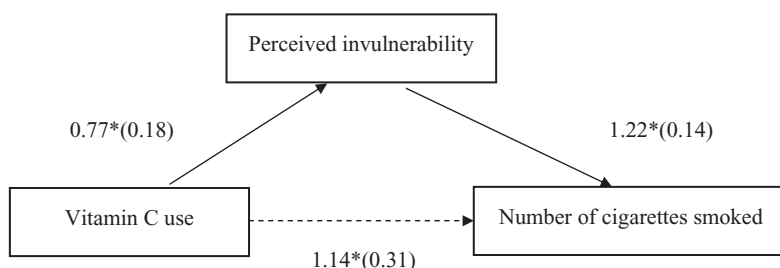


Figure 1 Mediation analysis in study 1. Numbers outside parentheses are unstandardized regression coefficients; numbers inside parentheses are the standard errors of regression coefficients. An asterisk indicates a P -value of less than 0.001

think about dietary supplements?', using a five-point scale ranging from 1 (very unsafe/very bad/very unfavourable/very negative/very unhealthy) to 5 (very safe/very good/very favourable/very positive/very healthy). Scores on these items showed internal consistency ($\alpha = 0.89$). The mean of the five items was computed to construct an index measuring attitudes towards supplements. A high index score indicated a positive attitude. As to criterion-related validity, a contrasted-group comparison between supplement users (mean = 2.85, SD = 0.90) and non-supplement users (mean = 2.18, SD = 0.92) indicated that supplement users held more positive attitudes than did non-users, $t_{78} = 3.23$, $P = 0.002$. Users with high index scores also reported a larger number of daily supplements taken, $r = 0.46$, $P < 0.001$.

Procedures

During recruitment, participants were asked to rate their attitudes towards dietary supplements, perceived invulnerability and nicotine dependence on the mFTQ. These questions were embedded in an ostensible questionnaire, and dietary supplement use was also recorded (Table 2). Upon participants' arrival at the laboratory, we excluded those who had taken supplements that day ($n = 10$).

Participants were assigned randomly to either the credentialled or the control group, with a block-randomization method used to control gender proportions between conditions. The credentials manipulation was identical to that in study 1. After the manipulation, each participant was led to the smoking room to complete a survey in which the perceived invulnerability measure was embedded. Number of cigarettes smoked and completion time were recorded as in study 1. During the debriefing, we conducted interviews to examine whether participants were consciously connecting their supplement use to their smoking behaviour. In addition, all participants correctly identified the kind of pills they took and none reported being aware that the manipulation and the dependent measure were related.

Results

Neither the number of daily supplements taken (mean = 0.66, SD = 0.59; $t_{78} = 0.56$, $P = 0.58$), nor nicotine dependence (mean = 5.61, SD = 1.18; $t_{78} = 0.62$, $P = 0.54$) differed between the credentialled and control conditions. Attitude towards dietary supplements (mean = 2.59, SD = 0.96; $t_{78} = -0.99$, $P = 0.32$), completion time on the survey (mean = 38.21, SD = 4.59; $t_{78} = 0.80$, $P = 0.43$) and prior perceived

Table 2 Participant demographics, descriptive statistics for the measures in study 2 and the effect of supplement use on boosted invulnerability and amount of cigarette smoking.

Community sample	Credentialled condition		Control condition	
	<i>n</i> = 40	%	<i>n</i> = 40	%
Gender				
Male	28	50.0	28	50.0
Female	12	50.0	12	50.0
Supplement users	23	62.5	25	57.5
Age (years)				
18–24	11	27.5	12	30.0
25–44	24	60.0	23	57.5
45+	5	12.5	5	12.5
	Mean	95% CI	Mean	95% CI
Number of daily supplements taken	0.70	(0.51–0.89)	0.63	(0.45–0.81)
Nicotine dependence	5.69	(5.36–6.02)	5.52	(5.13–5.91)
Attitudes towards dietary supplements ^a	2.48	(2.19–2.77)	2.69	(2.40–2.98)
Survey completion time (min.) ^b	38.63	(36.60–40.66)	37.80	(35.90–39.70)
Perceived invulnerability at pretest ^b	2.19	(1.99–2.39)	2.09	(1.90–2.28)
Perceived invulnerability at posttest ^c	2.65	(2.42–2.88)	2.15	(1.91–2.39)
Changes in perceived invulnerability ^c	0.47	(0.40–0.54)	0.05	(–0.08–0.19)
Number of cigarettes smoked ^d	2.80	(2.43–3.17)	1.65	(1.20–2.10)

^aAttitudes towards dietary supplements were measured on a scale ranging from 1 to 5. ^bNeither survey completion time nor perceived invulnerability at pretest differed between conditions. ^cParticipants who received the multivitamin use manipulation (the credentialled condition) showed a boost in perceived invulnerability, whereas participants under the control condition maintained a stable level. ^dParticipants under the credentialled condition smoked more cigarettes than the control participants. CI: confidence interval.

invulnerability (mean = 2.13, SD = 0.64; $t_{78} = 0.65$, $P = 0.52$) did not differ significantly between conditions. The results indicated that equivalent groups were established by random assignment (Table 2). Furthermore, nicotine dependence ($r = 0.18$, $P = 0.11$), number of daily supplements taken ($r = 0.14$, $P = 0.21$) and completion time on the survey ($r = 0.12$, $P = 0.30$) were not related to the number of cigarettes smoked (mean = 2.22, SD = 1.44). Therefore, these factors were not used as control variables in subsequent analyses.

Data on changes in perceived invulnerability support our hypothesized mechanism. As Table 2 shows, participants in the credentials group exhibited a boost in perceived invulnerability, $t_{39} = 13.88$, $P < 0.001$, whereas the control participants maintained a stable level, $t_{39} = 0.69$, $P = 0.50$. Furthermore, results supported the mediating role of perceived invulnerability (mean = 2.40, SD = 0.80): when we controlled for increased invulnerability (mean = 0.26, SD = 0.43; Sobel $Z = 4.22$, $P < 0.001$), the association between supplement use and cigarettes smoked was no longer significant (from $\beta = 0.40$, $P < 0.001$ to $\beta = 0.09$, $P = 0.34$). Interviews revealed that 57.5% of participants in the credentialled group felt that the effects of smoking were alleviated by prior use of multi-vitamins, suggesting that psychological licence may occur not only on a subconscious level but also via explicit beliefs.

Increased invulnerability was associated with attitudes towards dietary supplements, $r = 0.39$, $P < 0.001$. To examine the moderating role of attitudes towards dietary supplements, we standardized attitude scores, dummy-coded the credentials condition as 1 (0 = control) and computed an interaction term by multiplying the two. We then tested a regression equation predicting the number of cigarettes smoked using condition, attitude towards supplements and their interaction. This revealed a significant main effect of credentials, $\beta = 0.42$, $t_{76} = 4.26$, $P < 0.001$, partial $f^2 = 0.209$. Participants in the credentialled group smoked more cigarettes than did participants in the control group. These findings replicated the results of study 1. The attitude towards supplements was not a significant predictor, $\beta = -0.15$, $t_{76} = -1.07$, $P = 0.29$. More importantly, the hypothesized interaction between attitudes towards dietary supplements and condition was significant, $\beta = 0.43$, $t_{76} = 3.06$, $P = 0.003$, partial $f^2 = 0.122$.

To interpret the observed interaction, we tested simple slopes at various levels of the moderator [20]. At 1 SD below the mean score for attitudes towards supplements, the licensing effect was not significant: perceived supplement use only increased the number of smoked cigarettes by 0.33, $t_{76} = 1.05$, $P = 0.297$. As predicted, the licensing effect was significant at the mean attitude score: participants in the credentialled group smoked 1.20 cigarettes

more than did those in the control group, $t_{76} = 3.99$, $P < 0.001$. More importantly, the licensing effect was stronger at 1 SD above the mean attitude score: perceived supplement use increased tobacco consumption by 2.07 cigarettes, $t_{76} = 8.77$, $P < 0.001$.

In short, the results supported our contention that credentials created by supplement use can increase smokers' comfort with consuming more cigarettes. Taking dietary supplements seemed to enable greater recklessness with smoking, and this licence was more prominent as attitudes towards supplements became more positive.

DISCUSSION

Building on recent advances in the understanding of psychological licence, we hypothesized that perceived supplement use might restore health credentials, boosting perceived invulnerability and thereby disinhibiting the addictive behaviour of smoking. This link was supported by two studies showing that participants who believed they were taking a supplement were less likely to refrain from smoking (study 1) and subsequently smoked more cigarettes (studies 1 and 2). Perceived invulnerability mediated the relationship between supplement use and excess cigarette consumption. The present findings demonstrated that dietary supplement use may licence smokers to smoke more cigarettes. Smokers appear to perceive their own health as a general concept, so they can reward themselves for healthy behaviours in one domain (i.e. health-protective acts) by engaging in unhealthy behaviours in a different domain (i.e. smoking).

Our findings contribute to the literature in several important ways. First, we provide evidence showing that health credentials can interfere with self-regulation of smoking. These data differ from those showing licensing effects in other health-related choices (e.g. dieters who perceived greater progress towards their ideal weight were more likely to choose a tasty but fattening candy bar over a healthy snack [21], and consumers sampled more when a food item was framed as healthful than when it was framed as tasty [22]). Secondly, our mediation analyses supported the idea that the licensing effect operates by providing a temporary boost to the relevant component of self-concept (i.e. perceived invulnerability). Finally, our findings suggest that smokers with a more positive attitude towards supplements may generate a higher-level illusion of invulnerability, which makes them more susceptible to licensed smoking. This research indicates that dietary supplement use may be connected more closely to smoking behaviour than thought previously.

Although the current studies point collectively to a link between supplement use and increased smoking,

we acknowledge that our designs were limited to one dichotomized independent variable. Our findings focused on the immediate effects of two conditions in a laboratory setting. Licensing in naturalistic settings is less well understood. Caution should be exercised when generalizing to everyday contexts. Additionally, smokers who perceive a high health risk from their smoking may take supplements to mitigate their concern. Future research may examine how health risks related to smoking would influence smokers' supplement use.

Self-exempting beliefs, conceptualized as cognitive dissonance-reduction strategies, develop when there is a perceived inconsistency between beliefs and behaviours engaged [23]. Chapman *et al.* [24] found that fewer smokers than ex-smokers accepted that smoking causes illness, and smokers also maintain more self-exempting beliefs. This research suggests that health credentials established by taking supplements may temporarily boost these beliefs, leading smokers to loosen self-regulation of subsequent cigarette consumption. In conclusion, our results indicate that smokers' perceived invulnerability mediates the connection between supplement use and tobacco use. Given that smokers may also use supplements as a means to make up for the health hazard of smoking, those who rely on supplements for health protection may be at risk for consequences involving excessive supplement use and licensed smoking. After taking supplements, smokers should monitor diligently whether an illusory sense of invulnerability is activated and guard against recklessness with smoking. Interventions that remind smokers to be aware of the licensing effect may help to translate increased supplement use into increased tobacco control.

Declarations of interest

None.

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