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Original Article

Effects of a Transtheoretical Model-based Board Game on Processes of Change, Self-efficacy, and Decisional Balance in Adolescent Smokers: A Four-arm Randomized Controlled Trial

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ABSTRACT

OBJECTIVE: The stage of behavioral change, self-efficacy, and decisional balance potentially influence adolescents' smoking cessation. Gamified and Board Game (BG)–based interventions may influence adolescents by promoting active participation and peer interaction, and by offering an alternative to conventional didactic smoking cessation approaches. This study compared the effectiveness of a structured, Transtheoretical Model-based (TTM) BG, a combined approach BG and Tobacco Cessation Education (TCE), and a control group.

MATERIAL AND METHODS: A 4-arm, single-blind, randomized controlled trial was conducted; 103 adolescents were recruited from a high school. Participants were randomized into four groups: BG and TCE, Combined Interventions and Control. Sociodemographic Form, Processes of Change Scale (PCS), Self-Efficacy Scale (SES) and Decisional Balance Scale (DBS) was used to collect data.

RESULTS: Statistical analysis was performed using a repeated-measures ANOVA and a post-hoc test. At post-test, the BG group showed significantly higher PCS scores than control group (70.32±17.76 vs. 58.46±19.34 $P = 0.039$), with significant intragroup improvement over time ($P = 0.024$). Regarding SES, the BG group had significantly higher Habit Suppression subscale scores of the SES than control group at post-test ($P = 0.042$). The stage-of-change analysis revealed that 4.9% progressed to the action stage. DBS showed baseline differences, but remained stable over time.

CONCLUSION: Integrating TTM-based approaches with innovative gamification strategies, such as BGs, effectively supports behavioral change processes in adolescents. Findings suggest that a BG designed according to the TTM may be an effective approach to influencing adolescent smoking cessation behavior.

KEYWORDS: Addiction, adolescent, cessation, board game, nicotine, smoking, tobacco

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INTRODUCTION

Tobacco and nicotine products cause the deaths of millions of people each year and indirectly affect millions more.[1] The literature has shown that these products are particularly harmful to adolescents and children.[2]

In Türkiye, the prevalence of tobacco use remains concerning. National data comparing 2023 and 2017 results indicated that 33.0% of those aged 15-29 years were current smokers, with rates of 44.9% among men and 20.6% among women.[3] The current prevalence rates are higher than those reported in the 2017 Global Youth Tobacco Survey.[4] These rising statistics indicate that effective and developmentally appropriate interventions are needed to address tobacco use among adolescents in Türkiye.

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Adolescence is a period of vulnerability during which unhealthy behaviors, such as tobacco and nicotine use, often emerge. Incomplete neurological development, including immature neural connections, increases adolescents' risk-taking tendencies, while their self-efficacy and decision-making skills may not yet be fully developed.[5] The Transtheoretical Model (TTM) describes the roles of self-efficacy and decisional balance in the behavioral change process. According to the TTM, high self-efficacy and well-developed decision-making skills are significant drivers of behavioral change.[6-8]

According to Bandura,[9] self-efficacy is defined as an individual's judgment of their capacity to successfully carry out a specified action, to control events, or to achieve a certain level of performance. Individuals with a strong sense of self-efficacy may resist problematic behaviors, such as smoking.[10,11] Liu et al.[12] emphasized the importance of empowering adolescents by providing decision-making skills that enable them to resist influences promoting tobacco use, such as product appeal, social pressures, and conflicting information. Innovative educational strategies, such as experiential learning tools, can provide engaging and interactive ways to promote awareness and behavioral modification.[13]

The present study aimed to evaluate the effects of (1) a Board Game (BG) structured according to the TTM, (2) tTobacco Cessation Education (TCE) and (3) their combined use on processes of change, self-efficacy, and decisional balance among adolescent smokers.

MATERIAL AND METHODS

Study Design and Ethics

This study was a single-blind, four-arm, parallel-group randomized controlled trial to evaluate the effects of a BG and of smoking cessation education on self-efficacy and decisional balance processes among adolescents. The methodological details were described in the previously published article and thesis.[14,15] The study was performed in accordance with the Declaration of Helsinki and received ethical approval from the Eskişehir, Osmangazi University Ethics Committee (decision no: 09, date: 21.11.2017) and the Ministry of National Education Ethics Committee (no: 3401438, date: 16.02.2018). We have now explicitly labeled this as a prospectively designed trial with retrospective registration. We emphasize that the study protocol, including intervention tools and outcome measures, was finalized and approved by the Ethics Committee in 2017, long before data collection began, thereby preserving the prospective integrity of the trial design. This randomized controlled trial was registered retrospectively at ClinicalTrials.gov (Identifier: NCT05477342). Participant recruitment was completed before trial registration because the study was initiated as part of a doctoral research project, which preceded the routine implementation of prospective trial registration at our institution.

Data Source and Relationship to Previous Publication

The data analyzed in the present study were derived from the same randomized cohort of participants (n = 103) included in a previously published article based on the author's doctoral research project. To ensure full transparency and compliance with International Committee of Medical Journal Editors guidelines, we clarify that, although the cohort is identical, the outcomes Processes of Change Scale (PCS), Self-Efficacy Scale (SES) and Decisional Balance Scale (DBS) are reported here for the first time and were pre-specified in the original doctoral trial protocol. This report is a preplanned secondary analysis of the psychosocial mechanisms of change distinct from the primary clinical outcome (nicotine dependence) published earlier. The previous publication reported the effects of the interventions on nicotine dependence, assessed using the Fagerström Test for Nicotine Dependence, and presented findings related to participants' stages of change. The present manuscript reports additional outcomes from the original randomized controlled trial, specifically processes of change, self-efficacy, and decisional balance. These measures were included in the original doctoral research framework and were prospectively assessed during the trial. However, findings related to these outcomes were not reported in the previous journal publication.[15]

Participants and Eligibility Criteria

The study population comprised students at the Mustafa Kemal Atatürk Vocational and Technical High School in Eskişehir, Türkiye, between October 2018 and January 2019. The inclusion criteria were (i) being a registered student at the specified school, (ii) smoking at least one cigarette per day, and (iii) providing voluntary informed consent to participate. To foster a sense of trust and ensure maximum inclusivity among the adolescent population, no additional exclusion criteria were applied. All students who met the inclusion criteria and volunteered were enrolled in the trial to avoid marginalization and to maintain the integrity of school-based peer groups.

The sample size was determined using G*Power v.3.1.9, based on Cohen's effect size for a mixed-design ANOVA with within-between interactions.[16] For a design with four groups and three repeated measures, assuming an effect size of 0.76, a type 1 error (α) of 0.05, and power (1-β) of 0.80, the minimum required sample size was calculated to be 96 participants. All 106 eligible students who volunteered were included in the final sample to account for potential attrition. However, due to incomplete survey responses, the final number of participants was gathered 103.

Randomization and Allocation

Students were randomly assigned to one of four parallel groups with a 1:1:1:1 allocation ratio: BG, TCE, Combined Intervention (CI), and Control (C). The random allocation sequence was generated by an independent researcher not involved in recruitment or intervention delivery, ensuring complete separation of roles. Randomization was performed using a computer-generated random number sequence (Microsoft Excel) with permuted blocks of varying sizes (e.g., 4 and 8) to ensure balance and prevent predictability (Figure 1). To ensure allocation concealment, the sequence was maintained in a password-protected file accessible only to the independent allocator. Following enrollment and pre-assignment of participants, the principal researcher sequentially requested group assignments. The participants were informed of their

assigned group. Given the nature of the interventions, blinding of participants and researchers during the implementation phase was not feasible; however, group assignments were concealed from the data analyst.

Intervention

The interventions were implemented over 12 weeks and consisted of weekly 45-minute sessions conducted in a school setting. The interventions were designed according to the TTM and previously validated in the study protocol described by Can[15] and Can and Örsal.[16] The interventions were as follows:

TCE: Participants received structured education sessions tailored to their specific "Stages of Change" (Precontemplation, Contemplation, and Preparation). The educational content focused on increasing awareness of the harms of tobacco and on developing coping strategies. Groups were dynamically reorganized weekly based on the participants' progression through the TTM stages (E1, E2, E3).

BG: Participants played the "Pickklop" BG in small groups of three or four (16 distinct groups coded G1-G16). The game is a cognitive-behavioral tool designed to strengthen decisional-balance skills and social resistance to smoking through interactive scenarios and peer learning.

CI (Game + Education): This group received both the TTM-based education and the Pickklop BG sessions on an alternating biweekly schedule.

Control: Participants in the control arm received only standard informational brochures regarding the health risks of tobacco use.

Outcomes

The original randomized controlled trial primarily evaluated nicotine dependence, which was reported in a previous publication. The present manuscript reports three additional TTM-based outcomes that were prospectively assessed as part

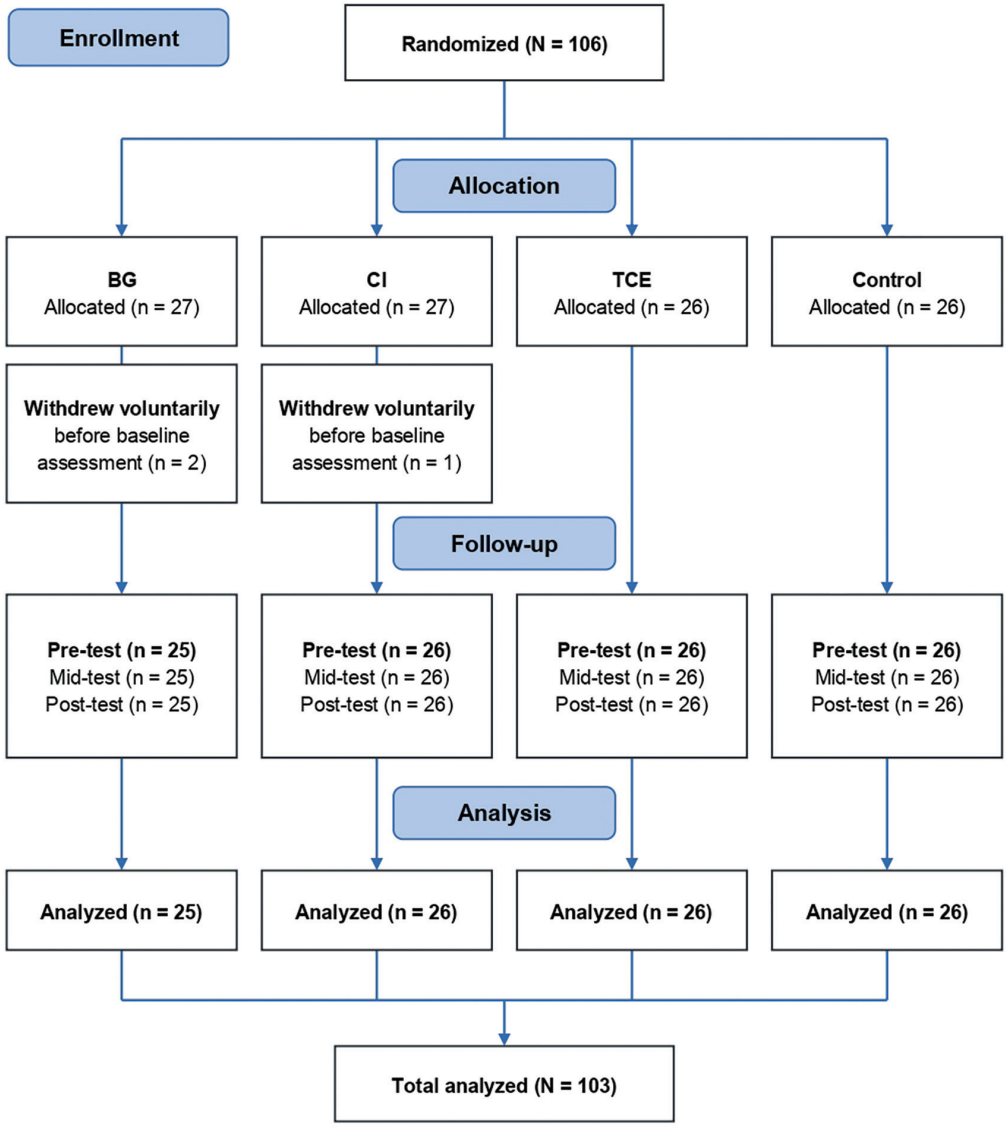


Figure 1. CONSORT flowchart of the study

BG: board game, CI: combined intervention, TCE: Tobacco Cessation Education

of the original doctoral research protocol: processes of change, self-efficacy, and decisional balance. Processes of change were assessed using the PCS, self-efficacy was assessed using the SES, and decisional balance was assessed using the DBS. We have now established a clear outcome hierarchy for this manuscript. The PCS total score is defined as the primary outcome, while the sub-dimensions of the SES and DBS are defined as secondary outcomes.

Data Collection and Follow-up: Interventions for the BG, TCE, and CI groups were delivered every two weeks by the same researchers to ensure consistency. Outcome measurements were conducted at three time points: baseline (T0), two weeks post-intervention (T1), and end of the 12th week (T2). All procedures were conducted following ethical approval and the attainment of written informed consent from parents and participants.

Measures

Stages of Change

The Stages of Change framework was developed by Prochaska and DiClemente[8] to identify the stages individuals experience while attempting to change behaviors. It uses a staging algorithm rather than a numerical scoring system. In this study, participants were categorized into one of five stages (Precontemplation, Contemplation, Preparation, Action, or Maintenance) based on their responses to specific questions regarding their current smoking status and their intention to quit within the next 30 days or within the next 6 months.

Processes of Change Scale

The PCS was used to evaluate the cognitive and behavioral strategies employed by adolescents during tobacco cessation. Originally developed by Prochaska and DiClemente[8] and adapted for adolescents by Pallonen et al.,[17] the scale assesses emotional and interpersonal factors influencing behavioral modification. It comprises 22 items across 11 sub-dimensions, with total scores ranging from 22 to 110. Higher scores indicate more frequent use of change-facilitating methods. The Turkish version, validated by Erol,[6] reported a Cronbach's alpha of 0.846. In this study, the scale's reliability was confirmed with an alpha of 0.85. This instrument provides critical insights into the internal mechanisms underlying changes in smoking behavior.

Self-Efficacy Scale

The SES was employed to assess adolescents' confidence in their ability to resist smoking in challenging situations. Developed as a 5-point Likert-type instrument, the scale consists of eight items, with total scores ranging from 8 to 40. Higher scores reflect a stronger perceived capability to maintain smoking cessation and to successfully modify behavior.[7] The SES comprises four distinct sub-dimensions: Negative Affect, Positive Social Environments, Habit Suppression, and Weight Control, each evaluated by two items. The Turkish validity and reliability of the scale were established by Erol,[6] who reported a Cronbach's alpha of 0.856.[6] In the present study, the scale's internal consistency was found to be 0.79.

Decisional Balance Scale

The DBS was used to assess the cognitive factors influencing adolescents' decisions to use tobacco. Originally developed by Velicer et al.[7] and later refined into a 12-item short form by Pallonen et al.,[17] the scale measures the perceived pros and cons of smoking. It consists of three sub-dimensions: Contributions to Socialization, Coping with Negative Emotions, and Harms of Smoking. Responses are scored on a 5-point Likert scale, with total scores ranging from 6 to 30. For the Turkish version validated by Erol,[6] Cronbach's alpha was 0.626.[6] Despite this relatively low baseline reliability, the scale remains a standard tool for assessing decisional conflict in TTM-based interventions. In the present study, the scale's internal consistency was found to be 0.65.

Statistical Analysis

Categorical variables were summarized as frequencies and percentages. All continuous data were reported as mean±standard deviation. Normality was assessed using the Shapiro-Wilk test, skewness, and kurtosis. A two-way repeated-measures ANOVA evaluated the time × group interaction. Mauchly's test was performed to assess the assumption of sphericity, and Greenhouse-Geisser corrections were applied where necessary. Bonferroni-adjusted pairwise comparisons were performed to examine differences across measurement times and simple group effects at each time point. Effect sizes were reported as partial eta squared (partial η^2), with 95% confidence intervals provided for pairwise comparisons. Statistical significance was set at $P < 0.05$.

RESULTS

The study was completed by 103 adolescents with a mean age of 16.29±0.95 years. The distribution of sociodemographic characteristics is shown in Table 1.

At baseline (pretest, T0; Table 2), 43.7% (n = 45) of the participants were in the precontemplation stage, 35.0% (n = 36) were in the contemplation stage, and 21.4% (n = 22) were in the preparation stage; there were no significant differences between groups ($P = 0.290$). By the post-test (T2), the distribution changed to 30.1% (n = 31) in the precontemplation stage, 43.7% (n = 45) in the contemplation stage, 21.4% (n = 22) in the preparation stage, and 4.9% (n = 5) in the action stage ($P = 0.251$). Within-group analysis showed a statistically significant change in the distribution of stages over time ($P = 0.002$).

Baseline PCS total scores did not differ significantly among the four groups ($P = 0.275$). At the 12-week follow-up, PCS scores were 70.32±17.76 in the BG group, 66.53±8.64 in the CI group, 64.00±10.80 in the TCE group, and 58.46±19.34 in the C group. A significant group effect was observed at the 12-week follow-up, $F(3, 99) = 2.889$, $P = 0.039$, partial $\eta^2 = 0.080$. Bonferroni-adjusted pairwise comparisons showed that the BG group had significantly higher PCS scores than the C group [mean difference (MD) = 11.858, $P = 0.031$, 95% CI (0.688, 23.029)] (Table 3). Within-group analyses over time revealed a statistically significant improvement in PCS scores in the BG ($P = 0.024$) and CI ($P = 0.000$) groups (Figure 2, Table 3).

Table 1. Sociodemographic characteristics of the participants by group (n = 103)

	*BG n (%)	*CI n (%)	*TCE n (%)	*C n (%)	**Total n (%)	*P* value***
Age groups						
16 and below	12 (48.0)	15 (57.7)	15 (57.7)	8 (30.8)	50 (48.5)	NS
17 and above	13 (52.0)	11 (42.3)	11 (42.3)	18 (69.2)	53 (51.5)	
Gender						
Female	14 (56.0)	14 (53.8)	10 (38.5)	18 (69.2)	56 (53.8)	NS
Male	11 (44.0)	12 (46.2)	16 (61.5)	8 (30.8)	47 (46.2)	
Grade						
9	1 (4.0)	2 (7.7)	0 (0.0)	2 (7.7)	5 (4.9)	NS
10	2 (8.0)	3 (11.5)	9 (34.6)	3 (11.5)	17 (16.5)	
11	9 (36.0)	13 (50.0)	6 (23.1)	5 (19.2)	33 (32.0)	
12	13 (52.0)	8 (30.8)	11 (42.3)	16 (61.5)	48 (46.6)	
Family type						
Nuclear	21 (84.0)	23 (88.5)	23 (88.5)	20 (76.9)	87 (84.5)	NS
Extended	1 (4.0)	1 (3.8)	1 (3.8)	3 (11.5)	6 (5.8)	
Single-parent	3 (12.0)	2 (7.7)	2 (7.7)	3 (11.5)	10 (9.7)	
Living arrangement						
Living with family	23 (92.0)	21 (80.8)	26 (100.0)	24 (92.3)	94 (91.3)	NS
Living outside the family	2 (8.0)	5 (19.2)	0 (0.0)	2 (7.6)	9 (8.7)	

Percentages for intervention and control groups* are calculated as column percentages, while the total sample column** represents row percentages (n = 103). ***Chi-square test was used for intergroup comparisons at baseline. Baseline sociodemographic characteristics of participants included in the analysis (n = 103)
BG: board game, CI: combined intervention, TCE: Tobacco Cessation Education, C: control, NS: not significant

Table 2. Comparison of groups by stage of change

	BG n (%)*	CI n (%)*	TCE n (%)*	C n (%)*	Total n (%)**	*P*
Pre-test						
Precontemplation	8 (17.8)	13 (28.9)	12 (26.7)	12 (26.7)	45 (43.7)	
Contemplation	9 (25.0)	11 (30.6)	8 (22.2)	8 (22.2)	36 (35.0)	NS
Preparation	8 (36.4)	2 (9.1)	6 (27.3)	6 (27.3)	22 (21.4)	
Within-group analysis /*P* NS						
Mid-test						
Precontemplation	8 (32.0)	12 (46.2)	16 (61.5)	7 (26.9)	43 (41.7)	
Contemplation	9 (36.0)	12 (46.2)	4 (15.4)	9 (34.6)	34 (33.0)	0.042
Preparation	8 (32.0)	2 (7.7)	6 (23.1)	10 (38.5)	26 (25.2)	***CI>C ***TCE>C
Within-group analysis /*P* NS						
Post-test						
Precontemplation	4 (16.0)	4 (15.4)	8 (30.8)	15 (57.7)	31 (30.1)	
Contemplation	13 (52.0)	17 (65.4)	8 (30.8)	7 (26.9)	45 (43.7)	
Preparation	5 (20.0)	5 (19.2)	8 (30.8)	4 (15.4)	22 (21.4)	NS
Action	3 (12.0)	-	2 (7.7)	-	5 (4.9)	
Within-group analysis /*P* = 0.002						
****Contemplation>precontemplation						
Repeated measures over time/*P* = 0.94						

Percentages for intervention and control groups* are calculated as column percentages, while the total sample column** represents row percentages (n = 103).
***Two-way repeated measures ANOVA was used for longitudinal analysis, and Bonferroni-adjusted tests were used for post-hoc pairwise comparisons.
BG: board game, CI: combined intervention, TCE: Tobacco Cessation Education, C: control, NS: not significant

The results for total SES and sub-dimension scores between the groups are presented in Table 4. At the 12-week follow-up, Habit Suppression scores were 6.80±2.06 in the BG group, 6.46±1.96 in the CI group, 6.00±2.29 in the TCE group, and 5.11±2.42 in the C group. A significant group effect was observed: $F(3, 99) = 2.843$, $P = 0.042$, partial $\eta^2 = 0.079$. Bonferroni-adjusted pairwise comparisons showed that the BG group had significantly higher Habit Suppression scores than the C group [MD = 1.685, $P = 0.044$, 95% CI (0.029, 3.340)] (Figure 3, Table 4).

The DBS scores are presented in Table 5 (Figure 4). Significant between-group differences were observed at baseline in Social Pros ($P = 0.003$), Coping Pros ($P = 0.009$), and total DBS scores ($P = 0.002$). Post hoc comparisons revealed that the TCE group had higher Social Pros scores than the BG and control groups. Conversely, Coping Pros and total DBS scores were higher in the TCE group than in the control group. At the mid-test stage, a significant difference between the groups was observed on the Coping Pros subscale ($P = 0.004$), with higher scores in the CI and TCE groups than those in the control group. No significant between-group differences were observed in Cons at any assessment, nor were any observed in any DBS subscale or total score at post-test. Within-group analyses showed no significant changes over time in any DBS subscale or in the total score.

DISCUSSION

The present study utilized the TTM as a framework to evaluate the effectiveness of diverse instructional interventions for adolescent smoking cessation. Our findings demonstrated that the "Pickklop" BG, both as a stand-alone intervention and when integrated with traditional educational strategies, led to significant improvements in adolescents' behavioral change processes. Specifically, the game-based intervention was associated with greater improvements in the cognitive and behavioral processes supporting smoking cessation than in the control condition. These findings suggest that interactive and gamified tools may enhance adolescents' engagement with behavioral change strategies by addressing their developmental and cognitive needs.

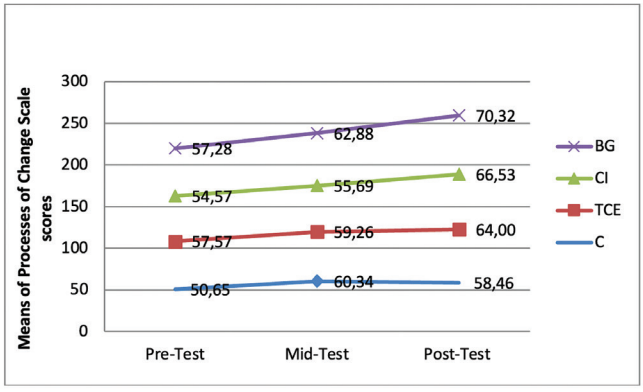


Figure 2. Mean Processes of Change Scale scores across study groups at baseline, mid-test, and post-test assessments

BG: board game, CI: combined intervention, TCE: Tobacco Cessation Education, C: control

The theoretical underpinning of our study aligns with the assertions of Prochaska and DiClemente[8] who emphasized that smoking cessation is not a binary outcome of success or failure but rather a dynamic, multi-stage process. Our findings support stage-tailored, interactive interventions that strengthen the cognitive and behavioral mechanisms underlying smoking cessation.

In our analysis of the stages of change, the proportion of adolescents in the precontemplation stage, while the proportion in the contemplation stage increased. Although intergroup differences at the final assessment did not reach statistical significance, progression of participants to the action stage occurred exclusively in the intervention arms. This transition, particularly in the game-based groups, suggests that interactive interventions may accelerate behavioral change more effectively than standard observation, supporting the TTM view of cessation as an incremental process.

The PCS represents cognitive and behavioral strategies used to adopt and maintain new behaviors.[17,18] According to the TTM, higher scores on the PCS are predictive of a greater likelihood of achieving long-term behavioral transformation.[7] The adolescents in the BG group demonstrated significantly greater utilization of these cognitive and behavioral strategies by the end of the study compared with the control group, highlighting the distinct advantage of the gamified approach in driving behavioral-change processes. The "Pickklop" BG was specifically designed as a structured group activity to increase awareness of tobacco-related behaviors, enhance understanding of addiction mechanisms, and foster the development of alternative coping strategies. Our results align with the TTM framework, which posits that the transition from precontemplation and contemplation to preparation and action depends on activation of cognitive processes, such as consciousness-raising and self-reevaluation. Our results are consistent with the work of Khazaal et al.,[19]

Table 3. Comparison of Processes of Change Scale scores between groups across time points

	BG Mean±SD	CI Mean±SD	TCE Mean±SD	C Mean±SD	*P*	Post-hoc
Behavior Change Process Scale						
Pre-test	57.28±10.39	54.57±12.87	57.57±17.15	50.65±15.50	NS	
Mid-test	62.88±21.36	55.69±11.13	59.26±13.65	60.34±15.15	NS	
Post-test	70.32±17.76	66.53±8.64	64.00±10.80	58.46±19.34	0.039	*BG>C
Repeated measures over time (p)	0.024	0.000	NS	NS		

Two-way repeated measures ANOVA was used for longitudinal analysis, and Bonferroni-adjusted tests were used for post-hoc pairwise comparisons.
BG: board game, CI: combined intervention, TCE: Tobacco Cessation Education, C: control, NS: not significant, SD: standard deviation

who demonstrated that the "Pickklop" intervention significantly reduced smoking relapse rates among adults compared with psychoeducation and control groups. While our study focused on an adolescent population, the parallels in cognitive engagement suggest that the game's interactive nature effectively addresses the internal triggers of nicotine dependence across different age groups. Furthermore, we believe that our results contribute to the growing body of evidence supporting TTM-based interventions as a robust strategy to promote smoking cessation among adolescents and young adults.[18,20,21]

When the temporal progression of PCS scores was examined, the stand-alone BG group and the CI group demonstrated substantial increases from baseline to post-test. Both intervention arms significantly outperformed the C group, suggesting that the "Pickklop" game serves both as a stand-alone strategy and as a synergistic component of broader educational programs. Our findings align with the observation by Harvey and Chadi[22] that cognitive and behavioral strategies intensify as adolescents progress toward cessation. While more intensive interventions in adult populations have yielded similar improvements, the significant PCS gains observed within our 12-week time frame suggest that the interactive and gamified design of "Pickklop" may serve as a catalyst, accelerating the behavioral change process over a shorter period than with conventional methods.

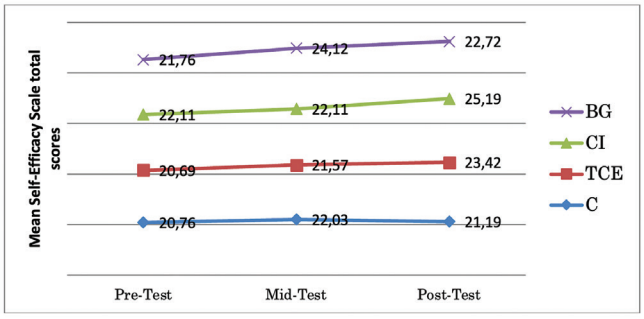


Figure 3. Changes in mean Self-Efficacy Scale total scores at baseline, mid-test, and post-test assessments

BG: board game, CI: combined intervention, TCE: Tobacco Cessation Education, C: control

Self-efficacy is defined as an individual's perceived capability to organize and execute the courses of action required to manage prospective situations.[9] In the context of tobacco control, self-efficacy serves as a primary determinant of smoking cessation, significantly influencing both quit intentions and long-term outcomes.[22] Research indicates that self-efficacy levels vary across developmental stages; adolescents with higher perceived competence are more likely to exert control over impulsive behaviors and to demonstrate greater resilience in modifying addictive behaviors.[23,24]

In the present study, a significant intergroup difference was identified in the 'Habit Suppression' sub-dimension of the SES. Specifically, adolescents in the BG group achieved higher scores compared with the C group, suggesting that the interactive nature of the intervention enhanced their perceived

Table 4. Comparison of groups by Self-Efficacy Scale

		BG Mean±SD	CI Mean±SD	TCE Mean±SD	C Mean±SD	*P*	Post-hoc
Negative affect	Pre-test	4.52±2.67	4.30±1.93	4.42±2.17	4.19±2.56	NS	
	Mid-test	5.24±2.87	3.80±1.95	4.57±2.57	4.03±2.12	NS	
	Post-test	4.44±2.64	4.65±2.07	5.03±2.82	4.61±2.56	NS	
Repeated measures over time/p		NS	NS	NS	NS		
Positive social environments	Pre-test	5.00±2.48	4.92±2.01	4.23±1.75	4.57±2.28	NS	
	Mid-test	5.52±2.61	4.23±2.08	4.73±2.20	4.57±2.11	NS	
	Post-test	4.88±2.24	5.34±1.83	5.03±2.25	4.46±2.43	NS	
Repeated measures over time/p		NS	NS	NS	NS		
Habit suppression	Pre-test	5.96±2.33	5.65±2.09	5.76±2.23	5.11±2.64	NS	
	Mid-test	6.28±2.86	6.00±1.95	5.34±2.46	5.76±2.35	NS	
	Post-test	6.80±2.06	6.46±1.96	6.00±2.29	5.11±2.42	0.042	*BG>C
Repeated measures over time/p		NS	NS	NS	NS		
Weight control	Pre-test	6.20±2.87	7.26±2.37	6.26±3.30	6.57±3.04	NS	
	Mid-test	7.04±3.42	7.96±2.64	6.76±3.32	7.76±2.74	NS	
	Post-test	6.84±3.15	8.26±2.23	7.53±2.81	7.15±2.86	NS	
Repeated measures over time/p		NS	NS	NS	NS		
Total score	Pre-test	21.76±8.50	22.11±6.22	20.69±6.09	20.76±8.24	NS	
	Mid-test	24.12±9.03	22.11±6.22	21.57±6.45	22.03±6.48	NS	
	Post-test	22.72±7.86	25.19±7.34	23.42±7.09	21.19±6.53	NS	
Repeated measures over time/p		NS	NS	NS	NS		

Two-way repeated measures ANOVA was used for longitudinal analysis, and Bonferroni-adjusted tests were used for post-hoc pairwise comparisons.
BG: board game, CI: combined intervention, TCE: Tobacco Cessation Education, C: control, NS: not significant, SD: standard deviation

capacity to restrain habitual smoking impulses. Although overall self-efficacy scores did not show statistically significant changes across groups or time points, which deviates from some TTM-based studies reporting global increases, our results highlight the specific impact of gamified tools on managing high-risk triggers.[23,25] This aligns with the systematic review by Kundu et al.,[26] which identified strong decision-making skills and the ability to manage behavioral cues as positive predictors of cessation among individuals aged 10–29 years. Our findings suggest that for adolescents, strengthening specific self-regulatory mechanisms, such as Habit Suppression, may be a more achievable and immediate outcome of short-term interventions than a total shift in general self-efficacy.

In accordance with social cognitive and decisional balance theories, the TTM posits that individuals' perceptions of the advantages and disadvantages of a behavior shift significantly as they progress through the stages of change.[9,18] Central to this cognitive transition is decisional balance, where the perceived costs (cons) of smoking are expected to increase, while the perceived benefits (pros) are expected to decrease as an individual moves from the precontemplation stage toward maintenance. This internal re-evaluation is critical for adolescents, as it facilitates a systematic comparison between the immediate social or emotional gains of smoking and the long-term health benefits of cessation.[18] Establishing a cognitive environment where the harms of tobacco use outweigh the perceived social rewards is a fundamental step in initiating the cessation process.

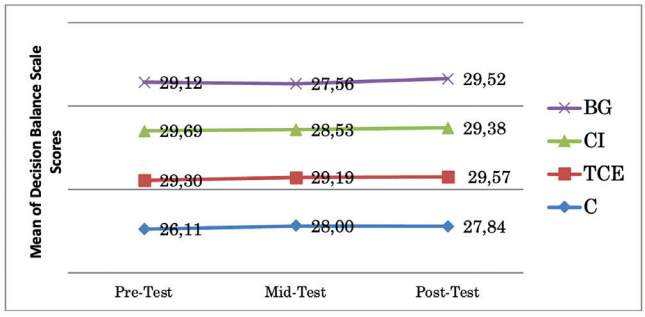


Figure 4. Mean Decisional Balance Scale scores across study groups at baseline, mid-test, and post-test assessments

BG: board game, CI: combined intervention, TCE: Tobacco Cessation Education, C: control

In the present study, no statistically significant longitudinal changes (time effect) were identified in the total or sub-dimension scores of the DBS across the three assessment points. Although a marginal increase in the cons (Harms of Smoking) sub-dimension was observed in the intervention groups at post-test, this shift did not result in a significant between-group difference. Statistically significant baseline differences in DBS scores were observed between the study groups despite randomization. Such baseline imbalances may occur by chance in randomized controlled trials, particularly when relatively small samples are allocated to multiple intervention groups, and do not necessarily indicate inadequate randomization. Evaluating the intervention effects using repeated-measures ANOVA, which assesses changes over time rather than relying solely on post-intervention comparisons, minimized the potential influence of these baseline differences on the estimated intervention effects. Nevertheless, the findings related to decisional balance should be interpreted with caution. To account for this baseline imbalance statistically, our analysis focused on the

Table 5. Comparison of groups by Decisional Balance Scale

		BG Mean±SD	CI Mean±SD	TCE Mean±SD	C Mean±SD	P	Post-hoc
Social pros	Pre-test	3.36±0.81	3.92±1.29	5.00±3.16	3.30±0.73	0.003	*TCE>BG *TCE>C
	Mid-test	4.44±3.26	3.61±0.98	4.23±2.45	3.76±1.65	NS	
	Post-test	4.24±2.71	3.80±1.26	4.30±2.57	4.61±3.02	NS	
Repeated measures over time/p		NS	NS	NS	NS		
Coping pros	Pre-test	9.84±3.61	9.76±2.55	10.34±3.14	7.50±3.46	0.009	*TCE>C
	Mid-test	8.64±3.97	9.88±3.05	10.57±3.21	7.42±2.80	0.004	*CI>C *TCE >C
	Post-test	9.96±3.79	8.34±2.24	9.34±3.12	9.30±3.68	NS	
Repeated measures over time/p		NS	NS	NS	NS		
Cons	Pre-test	21.32±5.85	20.69±4.45	22.38±6.48	19.07±7.87	NS	
	Mid-test	20.12±6.88	21.57±6.61	24.5±13.24	19.07±7.87	NS	
	Post-test	23.04±6.66	22.38±4.75	23.57±5.75	19.42±7.50	NS	
Repeated measures over time/p		NS	NS	NS	NS		
Total score	Pre-test	29.12±2.29	29.69±0.78	29.30±1.54	26.11±3.52	0.002	*TCE>C
	Mid-test	27.56±5.93	28.53±3.52	29.19±2.88	28.00±4.88	NS	
	Post-test	29.52±1.22	29.38±1.49	29.57±1.27	27.84±4.38	NS	
Repeated measures over time/p		NS	NS	NS	NS		

*Two-way repeated measures ANOVA was used for longitudinal analysis, and Bonferroni-adjusted tests were used for post-hoc pairwise comparisons
BG: board game, CI: combined intervention, TCE: Tobacco Cessation Education, C: control, NS: not significant, SD: standard deviation

Time×Group interaction, assessed using repeated-measures ANOVA, which evaluates the rate of change rather than absolute post-test values. We emphasize that these chance imbalances are common in smaller RCTs, and we acknowledge this as a specific limitation in interpreting the magnitude of the DBS findings. The literature suggests that perceiving smoking as harmful to oneself and others, and recognizing long-term addiction risks, are essential contributors to the decision-making process.[27] However, the lack of significant change in our sample may be attributed to the relatively short 12-week intervention, which may be insufficient to fully dismantle adolescents' well-established social and emotional perceptions of smoking. Our results suggest that while interactive tools can catalyze cognitive strategies (as seen in the PCS scores), shifting the fundamental balance of pros and cons may require more prolonged or intensive longitudinal support.

Previous TTM-based studies involving motivational interviewing with adolescents have reported that scores related to 'Coping with Negative Emotions' are typically lowest during the action stage, suggesting a reduced reliance on smoking as an emotional regulator as cessation progresses.[18,21] Furthermore, evidence indicates that theoretically grounded behavioral interventions, particularly those rooted in the TTM framework, hold substantial potential for promoting long-term smoking cessation among youth.[28] In our study, although the comparison of two distinct TTM-based approaches and the relatively limited intervention duration (12 weeks) may have attenuated some of the expected intergroup differences, the most pronounced increase in perceived harm was observed in the BG and CI groups. This trend underscores the specific advantage of gamified, interactive tools in enhancing risk perception and cognitive engagement, which are essential precursors for moving toward maintaining nicotine-free lifestyle.

Study Limitations

The findings of this study should be interpreted in light of several limitations. First, this study was conducted at a single center, which may limit the generalizability of the results to adolescents from different socio-cultural or geographic settings. Second, the 12-week intervention period and the follow-up duration may have been insufficient to capture long-term changes in complex psychological constructs such as general self-efficacy and decisional balance. Third, all data were based on self-reported measures, which are susceptible to social desirability bias. While biochemical verification (e.g., carbon monoxide or cotinine testing) is often preferred in smoking cessation research, it was not used in this school-based study because of ethical concerns about participant confidentiality. Given that smoking is legally prohibited for minors and subject to school disciplinary policies, implementing invasive biological testing could have exposed participants to potential social or administrative harm. By prioritizing a "confidentiality-first" approach, we aimed to foster honest self-reporting and ensure the safety of the adolescents involved. Furthermore, this report focuses on the "psychosocial mediators" of change (TTM constructs) rather than on absolute abstinence rates. Nevertheless, future research incorporating multi-center designs, longer follow-up periods, and, where ethically feasible, biochemical verification (e.g., carbon monoxide or cotinine testing) would provide more robust evidence regarding the sustained impact of gamified smoking cessation interventions.

CONCLUSION

This study demonstrates that a TTM-based BG, whether implemented independently or as part of a combined educational program, facilitates readiness for behavioral change and significantly enhances cognitive and behavioral change processes among adolescents. Given that adolescents are often a "hard-to-reach" population for traditional cessation programs, the integration of gamified strategies into school-based health curricula offers a promising, engaging, and effective approach. These findings suggest that interactive BGs can serve as a catalyst for promoting nicotine-free lifestyles by addressing the unique developmental needs of adolescents.

Ethics

Ethics Committee Approval: The study protocol was approved by Eskişehir Osmangazi University Non-interventional Ethics Committee (date: 21.11.2017, decision no: 80558721/G-313).

Informed Consent: All procedures were conducted following ethical approval and the attainment of written informed consent from parents and participants.

Footnotes

Authorship Contributions

Concept - Design - Data Collection or Processing - Analysis or Interpretation - Literature Search - Writing: All authors contributed equally to this study.

Conflict of Interest: No conflict of interest was declared by the authors.

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