Addictive Behaviors 182 (2026) 108756

Contents lists available at ScienceDirect

Addictive Behaviors

journal homepage: www.elsevier.com/locate/addictbeh

Bidirectional associations between protective behavioral strategies for cannabis use and cannabis outcomes: A cross-lagged longitudinal approach

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ARTICLE INFO

Keywords:
Cannabis
Protective behavioral strategies
Young adults
Within-person
Cross-lagged
Sex

ABSTRACT

Although the use of cannabis Protective Behavioral Strategies (PBS) is associated with lower consumption and fewer harms, most research has relied on cross-sectional designs, leaving the within-person directionality of these associations unclear. This study examined the bidirectional associations between PBS use and cannabis outcomes (frequency, quantity, and negative consequences) over a 15-month period and explored sex differences. We employed a three-wave longitudinal design (baseline, 3-, and 15-month follow-ups) and used a targeted sampling procedure to recruit a community-based sample of young adults who reported past-month cannabis use (n = 612; M_{age} = 21.04; 61.2% = male; 40.8% = university students). Random-intercept cross-lagged panel models disentangled stable between-person differences from within-person change and tested for sex invariance. At the between-person level, greater PBS use was associated with lower cannabis frequency, quantity, and negative consequences. At the within-person level, increased PBS use predicted subsequent reductions in cannabis use frequency, but not in quantity or consequences. Conversely, experiencing higher-than-usual negative consequences predicted subsequent increases in PBS use. No other significant cross-lagged effects were observed. Multigroup analyses revealed that these longitudinal associations were invariant across sex. Overall, findings provide novel evidence of the dynamic role of PBS, indicating that they function both as a protective factor and as a self-regulatory mechanism activated by adverse experiences. The stability of these associations across sex suggests that PBS-based interventions may operate through similar longitudinal mechanisms for men and women.

1. Introduction

The use of cannabis is associated with a variety of adverse outcomes, including mental health and cognitive impairments (Grigsby et al., 2023), cannabis use disorder (Connor et al., 2021), risky sexual behavior, and impaired driving (Memedovich et al., 2018). The prevalence of cannabis use has steadily increased over the past decade, particularly among young adults (United Nations Office on Drugs and Crime, 2025). This trend has been paralleled by growing scientific interest in protective behavioral strategies (PBS), which are cognitive-behavioral strategies that can be employed by young people before, during, after, or instead of cannabis consumption (Pedersen et al., 2017, e.g., limiting the amount of marijuana smoked in one sitting). PBS have been identified as a robust protective factor against heavy cannabis use and its negative consequences (González-Ponce et al., 2022; Grigsby et al., 2023).

Despite extensive research on PBS use, the existing studies have largely focused on college students and have predominantly employed cross-sectional designs (e.g., Bravo et al., 2017; Richards et al., 2021), with longitudinal research in broader young adult populations

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https://doi.org/10.1016/j.addbeh.2026.108756
Received 30 December 2025; Received in revised form 7 May 2026; Accepted 28 May 2026
Available online 29 May 2026

remaining scarce. To our knowledge, only one micro-longitudinal study using Ecological Momentary Assessment (EMA) has provided within-person evidence by capturing short-term fluctuations in PBS use and cannabis-related outcomes. Pearson et al. (2020), with a sample of 43 college students, found that greater daily use of PBS predicted a lower frequency of cannabis use, but not a lower quantity or fewer negative consequences.

Longitudinal research using cross-lagged panel models examines how two variables mutually predict each other over time while accounting for their prior levels (Kenny, 1975; Orth et al., 2021). These models provide within-person evidence on the directionality of the associations under study, allowing the testing of not only whether using more PBS than usual predicts subsequent reductions in negative consequences, but also whether experiencing more negative consequences than usual prompts individuals to increase their PBS use. Within the alcohol field, only one detected study to date has applied this approach. Napper et al. (2014) found that alcohol PBS related to the manner of drinking (e.g., drinking slowly, avoiding drinking games) predicted decreased alcohol-related consequences at a 3-month follow-up, whereas the inverse effect was not observed. However, in the cannabis domain, no studies to date have examined the bidirectional associations between PBS use and cannabis-related outcomes over time. Developing longitudinal research in the cannabis field that uses cross-lagged designs would help clarify the temporal direction of these associations, examining within-person changes over time rather than assuming that between-person differences reflect individual change. This could inform the development of tailored interventions that promote PBS use to reduce cannabis-related harms among young adults.

In the relationship between PBS and substance-related outcomes, sex has emerged as a relevant factor (Cox et al., 2024; Pearson, 2013). Although some studies have consistently found that women report greater cannabis PBS use than men (Bravo et al., 2017; Richards et al., 2021), it remains unclear whether the protective effect of PBS varies across sexes. To our knowledge, only two cross-sectional studies conducted with college students have examined this issue, showing no sex differences in the associations between PBS use and cannabis-related outcomes (Herchenroeder et al., 2022; Richards et al., 2021). Examining whether these protective effects vary longitudinally at the within-person level would help better inform the design of tailored interventions that take into consideration potential differences across sex.

This study aimed to examine: i) the bidirectional associations between cannabis-PBS use and cannabis-related outcomes (frequency and quantity of use, and negative consequences) using a three-wave longitudinal design spanning 15 months in a community sample of cannabis-using young adults; and ii) whether these associations differed by sex. Based on prior literature, we expect that greater use of PBS will be associated with lower frequency and quantity of cannabis use, as well as fewer negative consequences at the between-person level (González-Ponce et al., 2022; Grigsby et al., 2023). At the within-person level, the limited evidence (Pearson et al., 2020) showed that cannabis PBS use is associated with lower frequency of use, but not with quantity or related consequences. Building on robust between-person findings (González-Ponce et al., 2022; Grigsby et al., 2023), we nevertheless hypothesize that using more PBS than usual will prospectively predict decreases in all three outcomes. Regarding the reverse pathways, since no studies have examined whether cannabis-related outcomes predict subsequent PBS use we adopt an exploratory stance and do not anticipate hypotheses to this regard. Finally, based on previous evidence, we expect that the protective effect of PBS on cannabis-related outcomes will not differ by sex (Herchenroeder et al., 2022; Richards et al., 2021).

2. Method

2.1. Participants and procedure

We used a targeted sampling procedure (Watters & Biernacki, 1989) to recruit a community-based sample of 616 young adults aged 18–25 reporting past-month cannabis use. Four were excluded due to inconsistent responses. Baseline data were collected through face-to-face interviews (June 2022-July 2023). Follow-up assessments were conducted three and 15 months after baseline, using face-to-face and online procedures, respectively. The first two assessments took place at university facilities in Huelva and at local substance use-related organizations in Seville (South Spain).

The sampling process began by identifying settings where the target population was likely to be found, such as parks, squares, and areas with bars or pubs in Huelva and Seville. Subsequently, three trained field researchers (psychologists) visited the predetermined settings and approached individuals who appeared to meet the age criteria. Those interested in participating in the study and reporting cannabis use in the past year were later contacted by telephone to assess whether they met the inclusion criteria—namely, past-month cannabis use, residence in Huelva/Seville with no plans to relocate within three months, and Spanish fluency. Additionally, recruitment was further supported by informative posters placed across different districts in each city. Among participants, 128 (20.9%) were recruited directly by fieldworkers, 286 (46.7%) responded to the posters, and 198 (32.4%) were recruited through a controlled snowball sampling procedure (Goodman, 1961), which is a common approach in targeted sampling (Vervaeke et al., 2007; Watters & Biernacki, 1989). To avoid over-homogeneity, we limited referrals to five per participant and continuously monitored sample characteristics—age, sex, university status, and cannabis use profile—to adapt recruitment and ensure a heterogeneous sample (Thompson & Collins, 2002).

Three months after the baseline assessment (T1), a mixed-method strategy (Dillman et al., 2014) was employed to contact participants and invite them to take part in the first follow-up (T2). This approach has proven effective in reducing non-response bias and achieving high response rates in previous studies (DeLeeuw, 2018; Fernández-Calderón et al., 2021). One week before the end of the 3-month follow-up period, participants received a WhatsApp pre-notification thanking them for their previous participation, encouraging continued involvement, and informing them that a phone call would follow within 2–3 days to schedule the in-person session. Non-responders received two additional contacts: one via WhatsApp after 3–4 days and a phone call 6–7 days later. Of the baseline sample ($n = 612$), 82.5% ($n = 505$) completed the first follow-up questionnaire.

A second follow-up survey (T3) using the same mixed-method strategy was conducted 15 months after baseline. Contact procedures were similar to those used at T2, but this assessment was completed online through a personalized survey link. Of the baseline cohort, 432 participants (70.6%) completed the second follow-up questionnaire.

Participants could receive up to €35 in Amazon vouchers for completing all assessments (€15 for the T1-T2 assessments, and €5 for T3). The T1 and T2 questionnaires lasted approximately 75/60 min, respectively, while the online T3 survey took about 20 min. The study was approved by the Regional Committee for Bioethics Research of Andalusia (reference 0283-N-22) and was conducted in accordance with the principles of the Declaration of Helsinki.

Of the 612 participants ($M_{age} = 21.04$, $SD = 2.16$; 61.2% male), 35.6% cited a job as their main source of income; 30.1% self-identified as non-heterosexual; 40.8% were university students, and 65.5% were living with parents. The average score on the MacArthur Subjective Social Status Scale (socioeconomic status) was 5.86 (range 1–10, $SD = 1.51$). Over the past six months, 18.7% of participants reported cannabis use ≤ 3 times/month, 26.5% on 1–3 days/week, and 54.9% on ≥ 4 days/week. In the past month, participants reported using cannabis on an average of 18.16 days ($SD = 10.88$), with a mean weekly consumption of 8.50 g ($SD = 10.46$) and a typical daily consumption of 1.39 g ($SD = 1.34$).

2.2. Measures

Sociodemographic information *(baseline):* Age, biological sex, main source of income, sexual orientation, university status (currently enrolled or not), type of living arrangement, and subjective social status—measured with the MacArthur Scale of Subjective Social Status (Adler et al., 2000).

Cannabis Protective Behavioral Strategies *(all measures):* We employed the Spanish adaptation of the Protective Behavioral Strategies for Marijuana Scale (S-PBSC; Sánchez-García et al., 2024; original PBSM by Pedersen et al., 2017), which consists of 31 items assessing strategies used before, during, after, or instead of cannabis use to reduce consumption and related harms (e.g., "limit use to weekends"; "avoid using marijuana before work or school"). Responses were rated on a 6-point Likert scale (1 = *never*, 6 = *always*). Cronbach's $\alpha = 0.93$.

Cannabis Consumption *(all measures):* Participants reported the number of days they used cannabis in the past month. The amount of cannabis consumed in a typical week of the past month was assessed with the *Marijuana Use Grid* (Pearson & Marijuana Outcomes Study Team, n.d.), which divides each day of the week into six four-hour blocks (42 in total). Participants reported the grams of cannabis consumed in each block, with the total amount being summed. Given that both marijuana and hashish are consumed in comparable proportions in Spain (Observatorio Español de las Drogas y las Adicciones [OEDA], 2025), participants were asked to consider a typical week of cannabis use in the past-month and report, separately, the grams of each type consumed. To assist in estimation, images were provided showing marijuana and hashish in standardized quantities placed alongside bottle tops (Supplemental Figure-A). Total cannabis quantity was computed as the sum of marijuana and hashish grams consumed during a typical week of use.

Negative consequences of cannabis use *(all measures)*: The Spanish adaptation (Bravo et al., 2019) of the Brief Marijuana Consequences Questionnaire (Simons et al., 2012) was used. Although the original version includes 21 negative consequences that can be experienced after using cannabis in the past month (e.g., "the quality of my work or schoolwork has suffered because of my marijuana use"; "I have lost motivation to do things because of my marijuana use"), with responses recorded dichotomously (0 = no, 1 = *yes*), Item 5 was excluded following Bravo et al.'s (2019) recommendations. Cronbach's $\alpha = 0.80$.

2.3. Data analysis

Descriptive statistics and correlations were computed for the main study variables. Patterns of missing data were examined using Little's MCAR test, and multiple binary logistic regressions assessed whether missingness at waves 2 and 3 was associated with study variables at wave 1. T-tests and chi-square tests evaluated associations between missingness and sociodemographic variables.

Prior to estimating cross-lagged panel models, empty random-intercept multilevel models were used to compute Intraclass Correlation Coefficients (ICCs), quantifying variance attributable to between- and within-person differences. Longitudinal associations between PBS use, cannabis consumption, and its consequences were examined with bivariate Random Intercept Cross-Lagged Panel Models (RI-CLPM, Hamaker et al., 2015). This approach separates between-person variance (random intercepts) from within-person variance (latent residual factors), allowing examination of both cross-lagged effects (temporal precedence) and stable time-invariant associations.

Sex moderation was tested using multigroup RI-CLPMs. For each association, two models were compared: an unconstrained model and one in which cross-lagged effects, autoregressive effects, and correlations between intercepts were constrained to be equal across groups. Model comparisons were used to test parameter invariance, with lack of invariance indicating a moderating effect of sex.

Models were estimated in Mplus 8.7 using Maximum Likelihood with Robust standard errors (MLR), which accommodates non-normal data. Model fit was evaluated with χ^2, RMSEA, CFI, and SRMR. Good fit was indicated by non-significant χ^2, CFI > 0.95, and RMSEA < 0.06 and SRMR < 0.08; acceptable fit by CFI > 0.90, RMSEA < 0.08, and SRMR < 0.10 (Little, 2013). Nested model comparisons used the Satorra–Bentler scaled χ^2 difference test for robust estimation.

3. Results

3.1. Descriptive statistics

Cannabis PBS scores were negatively correlated with cannabis-related consequences and with both the frequency and quantity of cannabis use at all waves (Table 1). Across time, mean PBS scores increased, $F(1.77, 443.30) = 18.55$, $p < 0.001$, $\eta^2 = 0.07$, whereas cannabis consequences, $F(1.91, 478.76) = 15.03$, $p < 0.001$, $\eta^2 = 0.06$, frequency, $F(1.78, 629.51) = 72.31$, $p < 0.001$, $\eta^2 = 0.17$, and quantity, $F(1.49, 521.42) = 6.08$, $p = 0.006$, $\eta^2 = 0.02$, decreased.

3.2. Missing data

Participation rates were 82.5% at T2 and 70.6% at T3. Little's MCAR test indicated that missingness was not completely at random, $\chi^2(92) = 315.79$, $p < 0.001$. Logistic regression showed that cannabis quantity at T1 predicted missingness ($b = 0.04$, $p = 0.001$, OR = 1.04). Non-university participants were more likely to drop out, $\chi^2(1) = 9.02$, $p = 0.003$, Cramer's V = 0.13, and reported higher cannabis use, $t(608) = 6.29$, $p < 0.001$, $d = 0.54$. Full Information Maximum Likelihood estimation was used to handle missing data, and sex, age, and college status were included as covariates.

3.3. RI-CLPM findings

Intraclass Correlation Coefficients indicated that 60–71% of the variance in study variables reflected between-person differences, supporting the use of RI-CLPMs.

For the association between cannabis PBS and use frequency, the RI-CLPM showed good fit, $\chi^2(13) = 17.82$, $p = 0.164$, CFI = 0.997, RMSEA = 0.025, SRMR = 0.020, and fit significantly better than the traditional CLPM, $\Delta\chi^2(3) = 61.10$, $p < 0.001$. The model revealed a strong negative correlation between random intercepts and significant cross-lagged effects from PBS to frequency (T1 → T2, T2 → T3), indicating that greater-than-usual PBS use predicted lower subsequent frequency of cannabis use. No reverse effects were found (Fig. 1).

For the association between PBS and cannabis quantity, cannabis quantity was log(x + 1) transformed prior to model estimation to address the severe positive skewness observed at T2 and T3 (see Table 1). The RI-CLPM yielded excellent fit, $\chi^2(13) = 10.15$, $p = 0.682$, CFI = 1.00, RMSEA = 0.000, SRMR = 0.017, and fit significantly better than the traditional CLPM, $\Delta\chi^2(3) = 47.71$, $p < 0.001$. The model showed a strong negative correlation between random intercepts and no significant cross-lagged effects (Fig. 2).

The RI-CLPM linking PBS and cannabis-related consequences also fit well, $\chi^2(13) = 15.16$, $p = 0.298$, CFI = 0.998, RMSEA = 0.017, SRMR = 0.016, and outperformed the traditional CLPM, $\Delta\chi^2(3) = 37.44$, $p < 0.001$. The model indicated a negative correlation between random intercepts and a significant cross-lagged effect from consequences T1 → PBS T2, suggesting that experiencing more negative consequences predicted increased PBS use at follow-up (Fig. 3).

3.4. Multigroup RI-CLPM findings

Results of the multigroup analyses are presented in Table 2. Each RI-CLPM was estimated separately for males and females, controlling for age and college enrollment. Both unconstrained and constrained models showed good or acceptable fit. Constraining cross-lagged and

Table 1
Descriptive statistics and correlations for study variables.

	1	2	3	4	5	6	7	8	9	10	11	12	Mean *(SD)*	Skew	% 0s
1. PBS at Time 1	–												118.30 (29.07)	−0.29	0
2. PBS at Time 2	.801	–											122.42 (29.94)	−0.48	0
3. PBS at Time 3	.624	.708	–										127.05 (32.30)	−0.40	0
4. Cannabis frequency at Time 1	−.647	−.565	−.491	–									18.16 (10.88)	−0.24	0
5. Cannabis frequency at Time 2	−.630	−.670	−.505	.781	–								16.09 (11.62)	−0.03	7.7
6. Cannabis frequency at Time 3	−.526	−.561	−.626	.661	.646	–							11.08 (12.02)	0.65	23.0
7. Cannabis quantity at Time 1	−.527	−.482	−.454	.507	.462	.425	–						8.50 (10.46)	2.71	0
8. Cannabis quantity at Time 2	−.416	−.460	−.484	.383	.436	.487	.635	–					6.03 (10.99)	8.13	7.9
9. Cannabis quantity at Time 3	−.302	−.314	−.294	.359	.358	.422	.425	.467	–				5.53 (12.32)	6.07	31.1
10. Consequences at Time 1	−.384	−.247	−.229	.372	.360	.261	.274	.139	.168				7.72 (4.20)	0.25	2.5
11. Consequences at Time 2	−.368	−.343	−.242	.370	.450	.291	.264	.236	.139	.692	–		6.63 (4.29)	0.45	4.3
12. Consequences at Time 3	−.285	−.269	−.380	.382	.376	.371	.295	.303	.274	.623	.623	–	6.61 (4.60)	0.37	10.6
N	611	466	292	612	505	391	610	505	386	612	466	292			

Note. PBS is the Protective Behavioral Strategies use; Cannabis frequency is number of days of cannabis consumption in the past week; Cannabis quantity is the number of grams used in a typical week; Consequences is cannabis-related consequences experienced in the last month. Percentage of zeros was calculated relative to valid cases at each wave. The correlation between Cannabis Frequency at Time 3 and Consequences at Time 2 was significant at $p < 0.05$. All other correlations were significant at $p < 0.01$.

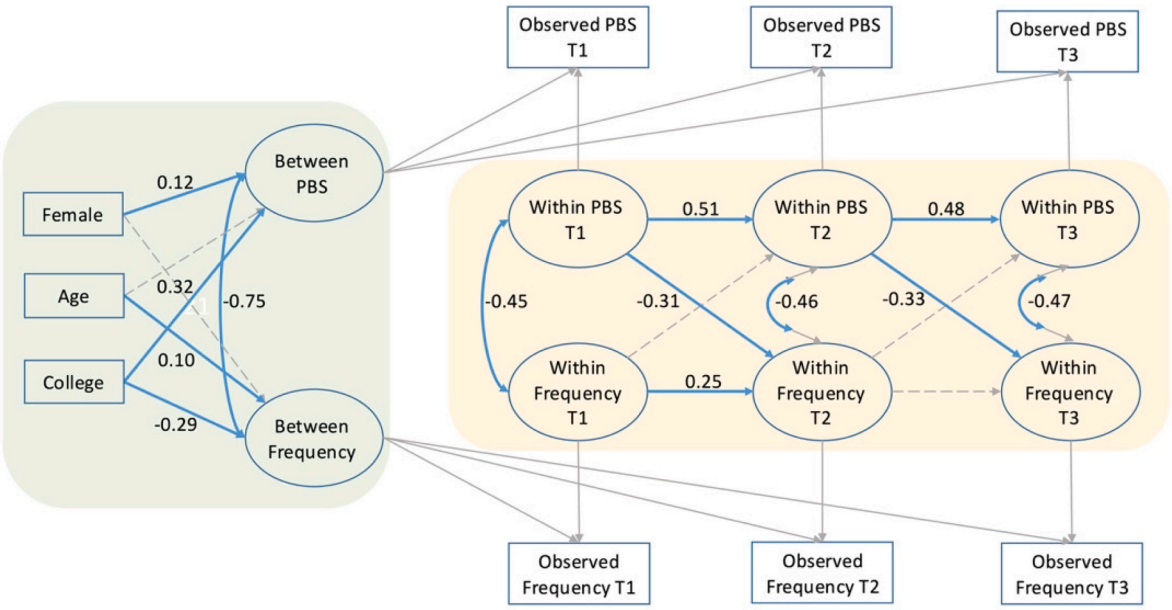

Fig. 1. *RI-CLPM for PBSC and cannabis use frequency Note*. RI-CLPM refers to the Random Intercept Cross-Lagged Model; PBSC stands for the Protective Behavioral Strategies for Marijuana Scale; Cannabis frequency refers to the number of days of cannabis use in the past week. Blue lines represent significant coefficients, while dotted gray lines indicate nonsignificant coefficients. All coefficients are standardized.

autoregressive effects, as well as correlations between intercepts, to equality did not worsen model fit, supporting parameter invariance—that is, the longitudinal relationships were consistent across sex.

4. Discussion

Although Protective Behavioral Strategies (PBS) use has been identified as a strong protective factor against cannabis consumption and its negative consequences, longitudinal evidence remains scarce. To our knowledge, this is the first study to longitudinally examine the cross-lagged relations between cannabis PBS and cannabis-related outcomes in a community-based sample of cannabis-using young adults. Our findings indicated that, at the between-person level, greater PBS use was associated with lower cannabis frequency, quantity and negative consequences. At the within-person level, increases in PBS use predicted subsequent decreases in cannabis use frequency, whereas cannabis use frequency did not predict later PBS use. Negative cannabis-related consequences predicted later increases in PBS use; however, PBS use did not predict subsequent negative consequences. These cross-lagged associations were invariant across sex.

As hypothesized, our results are consistent with the extensive cross-sectional evidence showing that greater PBS use is associated with lower cannabis use frequency and quantity, and fewer negative consequences at the between-person level (Grigsby et al., 2023). These findings contrast with the longitudinal evidence reported by Pearson et al. (2020) who did not find between-person associations between PBS use and cannabis-related outcomes. A potential explanation for this discrepancy

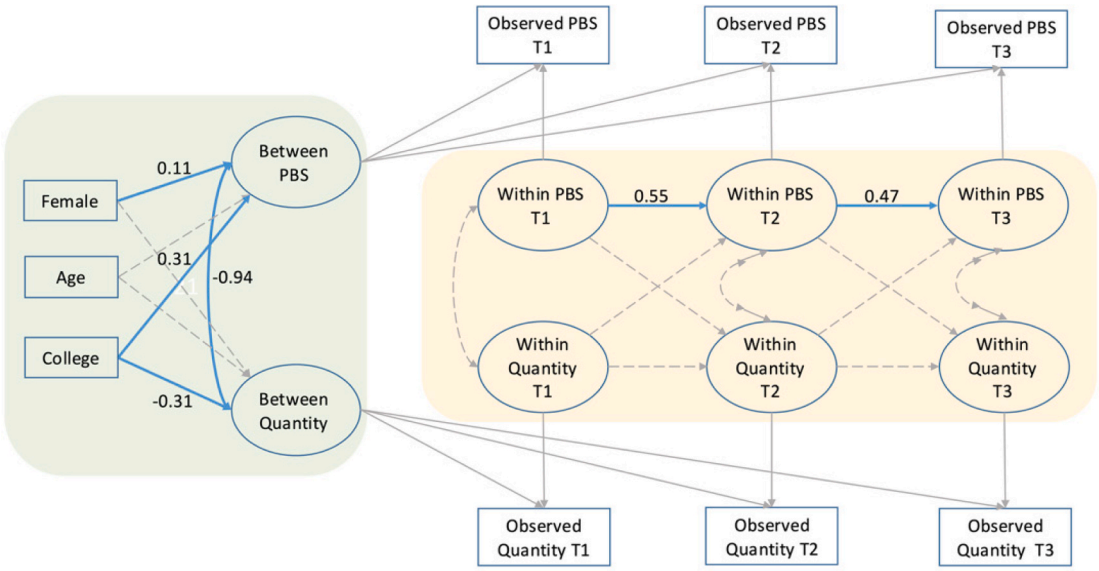

Fig. 2. *RI-CLPM for PBSC and MACQ Note.* RI-CLPM refers to the Random Intercept Cross-Lagged Model; PBSC stands for the Protective Behavioral Strategies for Marijuana Scale; MACQ stands for the Marijuana Consequences Questionnaire. Quantity = grams of cannabis used in a typical week, log(x + 1) transformed prior to model estimation. Blue lines represent significant coefficients, while dotted gray lines indicate nonsignificant coefficients. All coefficients are standardized.

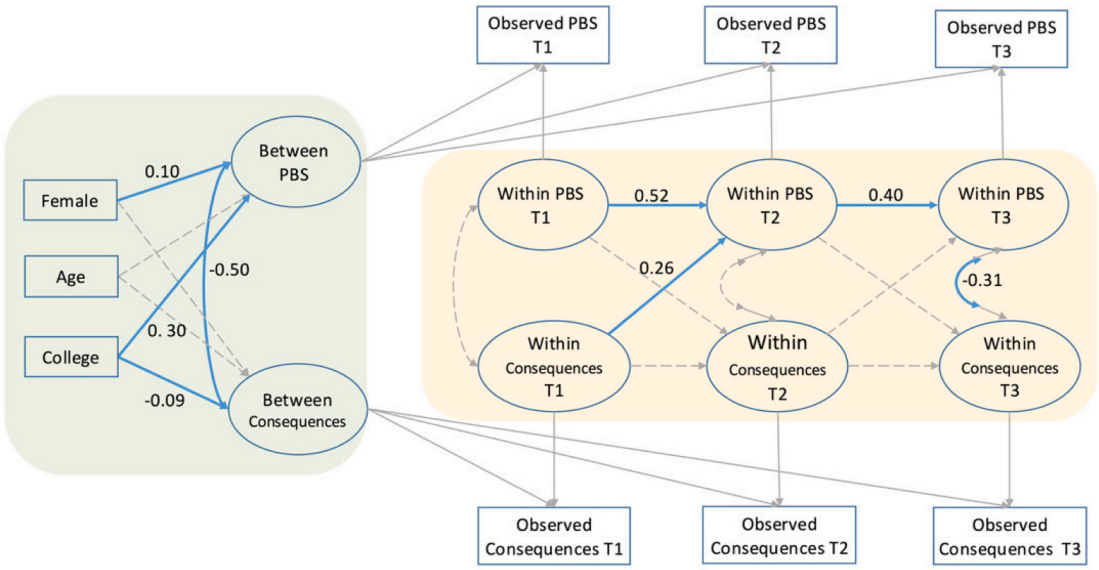

Fig. 3. *RI-CLPM for PBSC and cannabis use quantity Note.* RI-CLPM refers to the Random Intercept Cross-Lagged Model; PBSC stands for the Protective Behavioral Strategies for Marijuana Scale; Cannabis quantity represents the number of grams consumed in a typical week. Blue lines represent significant coefficients, while dotted gray lines indicate nonsignificant coefficients. All coefficients are standardized.

lies in the fact that the micro-longitudinal study conducted by Pearson and colleagues employed a rather small sample (n = 43) which limits statistical power to adequately detect between-subject effects. In addition, their selection of only 12 strategies from the original 50-item pool of the PBSM (Pedersen et al., 2016) may also account for their results. Nevertheless, their item-level analyses revealed that some specific PBS were longitudinally associated with lower cannabis use frequency and fewer negative consequences at the between-person level.

At the within-person level, in coherence with previous longitudinal research (Pearson et al., 2020), we found that greater PBS use predicted subsequent reductions in cannabis use frequency. However, contrary to our hypothesis, no associations were found with quantity or negative consequences, which contrasts with findings from the alcohol field (Napper et al., 2014). This pattern may reflect the relatively long follow-up intervals used in our study, as longer time gaps allow for multiple contextual and behavioral changes to occur over time, which can dilute prospective within-person associations between self-regulatory and substance-related outcomes (Hagger & Hamilton, 2023). In addition, as shown by Pearson et al. (2020), the fact that the overall score in PBS use was not associated with cannabis frequency and consequences does not imply that certain strategies show utility in this regard. From an applied perspective, these findings suggest that PBS may be particularly useful as a target for reducing cannabis use frequency in prevention and intervention programs for young adults. Accordingly, such programs may benefit from emphasizing strategies that directly limit opportunities for use, such as restricting cannabis use to specific days or avoiding use before academic, work, or other important responsibilities.

An interesting finding in our study was that greater cannabis-related negative consequences predicted subsequent increases in PBS use at the short-term follow-up. This pattern is consistent with the idea that

Table 2
Fit statistics for sex single-group and multigroup RI-CLPMs.

	χ^2	*df*	*p*	*CFI*	*RMSEA [95% CI]*	*SRMR*
Relationship between PBS and cannabis frequency						
Single-group male	22.47	9	.008	.984	.064 [.031, .097]	.044
Single-group female	18.97	9	.025	.986	.069 [.023, .112]	.036
Unconstrained multi-group	41.36	18	.001	.985	.065 [.039, .092]	.041
Constrained multi-group	55.74	31	.004	.984	.051 [.029, .073]	.066
Constrained vs. Unconstrained comparison	14.88	13	.315			
Relationship between PBS and consequences						
Single-group male	15.44	9	.080	.989	.044 [.000, .080]	.034
Single-group female	11.09	9	.269	.996	.031 [.000, .084]	.031
Unconstrained multi-group	26.42	18	.091	.993	.039 [.000, .069]	.033
Constrained multi-group	48.62	31	.023	.984	.043 [.016, .066]	.083
Constrained vs. Unconstrained comparison	22.23	13	.052			
Relationship between PBS and cannabis quantity						
Single-group male	10.84	9	.287	.998	.023 [.000, .066]	.032
Single-group female	10.75	9	.294	.997	.029 [.000, .082]	.049
Unconstrained multi-group	21.59	18	.251	.997	.026 [.000, .060]	.039
Constrained multi-group	34.91	31	,287	.997	.020 [.000, .049]	.072
Constrained vs. Unconstrained comparison	13.47	13	.412			

Note. RI-CLPMs refer to Random Intercept Cross-Lagged Models; PBS stands for the Protective Behavioral Strategies use; Cannabis frequency refers to the number of days of cannabis use in the last week; Cannabis quantity represents the number of grams consumed in a typical week; Consequences refers to negative cannabis-related consequences experienced in the last month. All RI-CLPMs include age and college enrollment as covariates. In constrained models, autoregressive effects, cross-lagged effects, and the correlation between random intercepts are constrained. Constrained and unconstrained models are compared using Satorra-Bentler scaled chi-square difference tests. Following Chen (2007), |ΔCFI| values between unconstrained and constrained models were 0.001, 0.009, and 0.000 for the PBS–frequency, PBS–consequences, and PBS–quantity associations, respectively, all below the recommended invariance threshold of 0.010 for samples with $N > 300$. For the association between PBS and cannabis quantity, cannabis quantity was $\log(x + 1)$ transformed prior to model estimation.

experiencing undesirable consequences −often during periods of heavier or more problematic use- may prompt self-regulatory harm-reduction efforts, including greater PBS use. In contrast to alcohol studies in which baseline consequences did not predict later PBS use (e. g., Luebbe et al., 2009; Napper et al., 2014), our result suggests that cannabis-related harms are likely to translate into short-term increases in protective behaviors. Notably, this effect did not persist at the longer follow-up, which may indicate that the motivating impact of negative consequences is time-limited and depends on their recency. This finding suggest that young adults experiencing cannabis-related negative consequences may represent an ideal target group for interventions aimed at encouraging PBS use, which may be most effective when delivered shortly after such experiences. In addition, these results complement previous work identifying psychosocial determinants of cannabis PBS, such as norms or attitudes towards PBS (Romero-Pérez et al., 2026; Vera et al., 2025), suggesting that cannabis-related consequences (but not cannabis use frequency or quantity), may constitute an additional mechanism underlying PBS adoption.

Although men report higher levels of cannabis use (European Union Drugs Agency, 2025) and women inform greater PBS use (Richards et al., 2021; Sánchez-García et al., 2024), only two cross-sectional studies conducted with college students have examined whether the protective effects of cannabis PBS differ by sex, showing no differences (Herchenroeder et al., 2022; Richards et al., 2021). Extending this limited literature, our findings provide longitudinal evidence that the detected cross-lagged associations between PBS use and cannabis-related outcomes operate similarly for men and women. This suggests that the implications of our results in the promotion of PBS use among young adults may be similarly beneficial for both men and women.

5. Limitations and Future Directions

Several limitations should be considered when interpreting our findings. Although targeted sampling was used to enhance heterogeneity, attrition across waves was higher among participants with heavier cannabis use and non-university young adults, what may have influenced the observed longitudinal associations. Future studies should implement retention strategies specifically designed to engage young adults who use cannabis more heavily and individuals from more diverse, non-university populations, such as more frequent and personalized reminders, flexible data-collection procedures, or enhanced incentives tailored to sustained participation across waves. Second, increases in PBS use and decreases in cannabis use across assessments may partly reflect not only the longitudinal association tested in the present study, but also assessment reactivity—that is, behavioral change prompted by repeated measurement and self-monitoring of one's own substance use and related experiences (Meier et al., 2017). Future research should continue to use longitudinal within-person designs to better disentangle true behavioral change from assessment reactivity and other time-varying influences. Third, the extended time-frame between the second and third assessments may have reduced temporal sensitivity for detecting lagged within-person effects. Cross-lagged estimates are time-lag dependent, and longer lags can dilute associations as additional unmeasured contextual and personal changes accumulate between waves (Hagger & Hamilton, 2023). Future studies would benefit from more frequent assessments to better align the measurement schedule with the pace at which cannabis use, consequences, and PBS use fluctuate. Additionally, although prior research indicates that individual PBS differ in their functional relevance for specific cannabis-related outcomes (Pearson et al., 2020), we used the total PBS score to examine its associations with cannabis outcomes. Future longitudinal within-person studies may benefit from examining PBS at the item level, as understanding these fine-grained associations could inform intervention efforts by identifying which specific strategies are most effective in reducing particular outcomes. Finally, the present findings should be interpreted in light of the Spanish cannabis policy context. Spain does not have a legally regulated recreational cannabis market; private personal use is not subject to criminal prosecution, whereas possession or consumption in public spaces is subject to administrative sanctions (European Parliamentary Research Service., 2023). This legal

framework coexists with relatively high cannabis availability and one of the highest prevalence rates of cannabis use among young adults in Europe (EUDA, 2025). Taken together, this context may influence patterns of cannabis use and PBS use, and should be considered when generalizing these findings to more restrictive settings or to jurisdictions with fully legalized retail markets.

5.1. Conclusions

This is the first study to examine prospective, cross-lagged associations between cannabis-related PBS and cannabis-related outcomes using a within-person design over a 15-month period. Our findings showed that greater PBS use predicted reductions in cannabis use frequency over time, whereas experiencing more negative consequences led to increased PBS use in the short term. These results highlight the dynamic role of PBS, suggesting that they function both as a protective factor and as a self-regulatory mechanism activated by adverse experiences. Promoting PBS use may help reduce cannabis use frequency among young adults, with those reporting greater negative consequences representing a key target group for implementation. Furthermore, the similar longitudinal patterns observed across men and women indicate that such interventions may be equally effective regardless of sex.

6. Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work the authors used ChatGPT 5.1 and Gemini 3.0 in order to improve the language and readability of the manuscript. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

Ethics approval.

The study was approved by the Regional Research Bioethics Committee of the Health Council of the Andalusian Government (Spain; reference 0283-N-22) and conducted in accordance with the Declaration of Helsinki.

Consent to participate.

Informed consent was obtained from all individual participants included in the study.

Funding statement.

This work was funded by the Agencia Estatal de Investigación (Ministerio de Ciencia, Innovación y Universidades, Spain; PSICOCANN Project. MICIU/AEI//https://doi.org/10.13039/501100011033/) under grant number PID2020-118229RB-I00 (Principal Investigator: Fermín Fernández Calderón).

CRediT authorship contribution statement

Nehemías Romero-Pérez: Writing – review & editing, Writing – original draft, Visualization, Resources, Methodology, Investigation, Data curation, Conceptualization. **José Carmona-Márquez:** Writing – review & editing, Writing – original draft, Visualization, Software, Formal analysis. **Alberto Parrado-González:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Data curation. **Bella María González-Ponce:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology. **Agar Marín-Morales:** Writing – review & editing, Writing – original draft, Visualization. **Fermín Fernández-Calderón:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This work was funded by the Agencia Estatal de Investigación (Ministerio de Ciencia, Innovación y Universidades, Spain; PSICOCANN Project. MICIU/AEI//10.13039/501100011033/) under grant number PID2020-118229RB-I00 (Principal Investigator: Fermín Fernández Calderón). AMM is supported by the grant Juan de la Cierva JDC2022-049121-I, funded by MCIN/AEI/10.13039/501100011033 and by the European Union "NextGenerationEU"/PRTR. Funding for open access charge: Universidad de Huelva / CBUA.

The authors would like to thank Federaci ó n Andaluza ENLACE and Asociaci ó n Nazarena de Terapia de Apoyo, Rehabilitaci ó n e Inserci ó n Social (ANTARIS) for their invaluable support.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.addbeh.2026.108756.

Data availability

The data that support the findings of this study are openly available via the Open Science Framework repository at: https://osf.io/u79pr/overview?view_only=da511b2fea584abe8cd4dbf531766bb5.

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