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Using the theory of planned behavior to examine the environmental behavior of roadrunners in Taiwan

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Abstract

Background Road running and similar community events boost local economies but also generate significant disposable waste, raising environmental concerns. According to the Theory of Planned Behavior, eco-friendly intentions are influenced by attitudes, subjective norms, and perceived behavioral control. This study explores these psychological factors among Taiwanese road runners, highlighting their ecological accountability and aiming to impact both theory and practice of environmental behavior towards societal sustainable development.

Methods A total of 430 questionnaires were collected from people associated with a series of road-running events in Taiwan. Based on the Theory of Planned Behavior, the relationships between the key components such as attitude, subjective norms, perceived behavioral control, behavioral intention, and behavior were investigated. The survey questions were designed and adapted in accordance with the guidelines for Theory of Planned Behavior questionnaire construction proposed by Ajzen. Partial least squares—Structural Equation Modeling has been used in hundreds of studies across a wide range of disciplines and was used to explore these components and develop a pathway model.

Results The results indicated that when females participate in road-running events, their perceived behavioral control, behavioral intention, and behavior regarding environmental protection are higher than those of the males that were sampled. Road-running participants who are aware of environmental road-running events exhibit better attitudes toward promoting environmental protection and more likely to be influenced by subjective norms. Older road-running event participants tend to outperform their younger counterparts in all the key components that were investigated in this study.

Conclusions The findings supported the five hypotheses that were tested in this study. Moreover, when encouraging people to participate in road-running events, environmental intervention protection measures must be implemented to increase the public's awareness and knowledge of environmental protection at these types of events.

Keywords Environmental protection behavior · Marathon · Road-running · Theory of planned behavior

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1 Background

Road-running is a popular sport that involves running on measured courses along established roads, often as community-wide events that attract competitive athletes, recreational runners, and people from the community. In recent years, there has been a notable growing shift towards road-running, with many individuals choosing it as their preferred form of running rather than traditional tracks. Despite a temporary decline in road-running participation during the COVID-19 pandemic, interest in road-running events is rekindling as pandemic-related restrictions ease. Runners are drawn to road-running for its multifaceted benefits, encompassing physical enhancement, psychological well-being, self-confidence, and opportunities for social interaction [1]. For instance, previous research has indicated that younger runners often prioritize personal goal achievement and competition, while older runners view running as a leisurely physical activity [2, 3]. Given the increasing popularity of road-running, it is not surprising that there are numerous road-running events being organized across the globe. Racecourses certified by the Association of International Marathons and Distance Races or the International Association of Athletics Federations are becoming more attractive. Despite hosting such events can help boost the economies of local communities, they also generate a substantial amount of trash from disposable products, which have environmental impacts and are of concern [4]. For example, Taiwan's Greenpeace Environmental Protection Organization's 2018 annual report revealed that there were 784 road-running events held in Taiwan in 2017 whereby at least four million disposable cups were used. Notably, these events organized in the six metropolitan cities accounted for 55% of waste generated through bottled beverages, plastic containers, and various types of plastic packaging bags, which correlates to approximately 2.4 million disposable cups in six cities. Besides generating substantial amounts of plastic and other waste streams, these events often also distribute commemorative gifts to the participants such as T-shirts, with nearly two million shirts given out annually. These factors contribute to the considerable environmental cost associated with road-running events [5–7]. Although the economic benefits of road-running events to the community are important, the amount of waste generated and stress on the infrastructure can be substantial. Therefore, considering the impacts of sporting and social events on the local environment is crucial and effective waste management strategies to mitigate their negative effects on the environment must be implemented. Recognizing the environmental cost of holding road-running events, organizers are focusing on implementing environmental protection measures at international-level competitions where the event organizers seek to achieve "low carbon and plastic reduction" targets. Such environmental protection norms are gradually being incorporated into the planning process of road-running events at all levels, and green and sustainable event indicators are being taken more seriously in green road-running events. Studies indicate that eco-friendly road-running events enhance environmental attitudes and behaviors of runners and participants, which support sustainable purchasing choices. The shift towards environmentally responsible actions aligns with the broader trends at sporting events that are aimed to reduce environmental impacts and promote sustainability [8–10]. Current literature reveals that the intentions behind experience, knowledge, awareness and the attitudes of participants can have a substantial and significant influence on their level of engagement in reducing environmental impacts [2, 28, 29]. Previous studies in relation to road-running have explored several different aspects such as physical and mental health well-being[11, 12], footwear[13, 14], environment features and concerns[15, 16], landscapes and nature[17–19], event management and policies[20, 21], and environmental footprint[22, 23], while other studies have investigated road-running from the perspectives of corporate social responsibility[24, 25], socialization[26, 27], event organization[28, 29], and injuries and risks[30, 31]. Despite this extensive body of research, there remains a critical gap concerning the environmental impact of road-running events, particularly the increasing issue of plastic waste. When examining the environmental impact of large-scale sporting events, research conducted in Taiwan provides valuable insights. A study on the 2012 Tour de Taiwan indicated that, despite the lack of permanent infrastructure, the event generated tangible economic and environmental benefits for the host community through intangible factors such as social cohesion [32]. Research on marathon events in Taiwan further revealed that remote regions like Kinmen and Hualien experience more significant economic and environmental impacts compared to metropolitan areas such as Taipei [33] Additionally, a study of the Sun Moon Lake National Scenic Area found that visitors perceived cycling as a low-impact activity, while motorboating was regarded as the most environmentally harmful recreational activity [34]. These studies suggest that while large-scale sporting events in Taiwan bring economic and socio-cultural benefits, they also impose certain environmental challenges [35]. However, with proper management and planning, negative environmental impacts can be mitigated, and community cohesion and economic development can be strengthened. Furthermore, residents' positive attitudes toward hosting future events indicate the long-term potential

of large-scale sporting events in Taiwan. The Theory of Planned Behavior (TPB) posits that an individual's behavior is primarily driven by their behavioral intentions, which are influenced by their attitudes towards the behavior, subjective norms, and perceived behavioral control [36, 37]. TPB is one of the most widely applied theories in environmental behavior research, having demonstrated its predictive utility across various contexts (e.g. environmental conservation, education) and behaviors (e.g. health-related, consumer) [36, 37].

The Theory of Planned Behavior (TPB) has been extensively applied to investigate behaviors within the context of large-scale sporting events, demonstrating considerable robustness in predicting a variety of behavioral outcomes. For instance, research on the dependability of volunteers at major sports events has indicated that attitudes, subjective norms, and perceived behavioral control significantly predict volunteer behavior, thereby validating TPB as an effective framework for understanding volunteer reliability [38]. Similarly, TPB has proven effective in explaining spectators' intentions to attend sporting events, with attitudes, subjective norms, and perceived behavioral control identified as key determinants of attendance intentions [39]. Furthermore, TPB has been employed to understand volunteer motivations and their intentions to return for future events, highlighting the mediating roles of subjective norms and perceived behavioral control in predicting these intentions [40]. Collectively, these studies underscore the utility of TPB in examining various behavioral aspects of large-scale sporting events, providing a robust theoretical foundation for predicting and explaining participation, attendance, and volunteer behavior.

This analytical framework provides a robust lens through which roadrunner environmental protection behaviors can be measured and assessed. Specifically, understanding the attitudes of roadrunners towards environmental conservation, the social pressures they perceive about engaging in environmentally friendly behaviors, and their sense of control over performing such behaviors can offer greater insight into how to effectively address and mitigate the environmental impact of road-running events.

Therefore, this study seeks to fill the aforementioned gap by applying the TPB to investigate the environmental protection behavior of roadrunners, with a particular focus on plastic waste generation. Furthermore, this study tests the robustness of the model on a different sample and context, specifically the roadrunners in Taiwan. By doing so, it aims to not only contribute to the scholarly understanding of road-running from an environmental perspective but also to inform stakeholders and the public on implementing more sustainable practices and policies for organizing road-running and other sporting/social events. This approach is essential given the urgent need for all sectors, including sports and recreation, to play a role in addressing global environmental challenges.

According to the TPB, understanding the behavioral intentions of a people is critical for promoting their environmentally responsible behavior. These intentions are shaped by an individual's attitude towards a behavior, subjective norms, and perceived behavioral control, all of which contribute to the likelihood of engaging in such behaviors [41]. Developed by Ajzen [42], the TPB is a comprehensive model that has been used for understanding the psychological drivers of environmental behavior. This study applies the TPB to explore how psychosocial factors, such as attitude, subjective norms, and perceived behavioral control, influence the environmental actions of roadrunners [43–45]. These components collectively shape the runner behavioral intentions, providing insights into roadrunner environmental engagements and informing intervention strategies aimed at promoting sustainability [44].

The TPB has been widely used to explain intentions and behaviors, and uses attitudes as a predictor across various fields, such as waste recycling, water conservation, and environmental consumerism [46]. This highlights the flexibility and applicability of the TPB for examining the environmental actions of roadrunners, thereby reinforcing the rationale for this research study. When a person's attitude towards pro-environmental behavior becomes more positive, their expectations increase, making them more likely to believe in their ability to engage in such behavior and motivate others to follow suit [47].

Environmental protection is thought to be heavily reliant on human behavioral patterns, which include identifying the behavior that requires change, examining the main factors that produce that behavior, designing and implementing interference measures to change polluting behaviors and reduce environmental impacts, and assess the performance of interference measures [48].

The social norm refers to the perceived external social pressure to perform a specific behavior [42]. For example, people may quit smoking if they believe it is unhealthy or if they believe important people want them to quit. The participant's PBC should also be considered, given that people cannot fully control their "acts of will." [49]. It was pointed out that attitude must be measured for specific behaviors in order to measure the correlation between attitude and behavior. For example, there is usually no correlation between climate change attitude and driving behavior. Even people who are concerned about climate change will drive because there is no direct relationship between climate

change attitude and the act of driving. In other words, while general attitudes may not affect behavior directly, behavior-specific attitudes can influence behavioral intentions, which in turn lead to changes in behavior [50].

Perceive behavioral control refers to the ability of an individual to control the external environment that subsequently led that person/individual to the exhibit a behavior [51]. Here, perceived behavioral control is considered to represent the actual control because it includes the impact of behavioral intention on behavior [52]. In TPB, behavioral intention is regarded as a key determinant of behavior, and the greater the participation in behavioral intention, the more likely a behavior will be performed [42].

1.1 Research hypothesis

This study, anchored in the TPB [42] methodology seeks to elucidate Taiwanese road runners' environmental protection behaviors. By integrating these hypotheses into a TPB framework, the influence of Attitudes (AT), Subjective Norms (SN), Perceived Behavioral Controls (PBC), Behavioral Intentions (BI), and Behaviors (BE) on the environmental behaviors of road runners can be better understood and validated. Based on the extant literature discussed earlier, the following hypotheses are proposed.

1.1.1 Hypothesis 1 (H1)

Roadrunner's attitude (AT) towards protecting the environment positively influence their behavioral intention (BI) to protect the environment.

This hypothesis is grounded in the premise that positive attitudes towards environmental conservation are crucial for fostering the intention to undertake sustainable actions [42, 53]. For instance, Bamberg and Möser [54] found that individuals with favorable environmental attitudes are more likely to exhibit a strong intention to participate in eco-friendly behaviors.

1.1.2 Hypothesis 2 (H2)

Roadrunner's subjective norm (SN) towards protecting the environment positively influence their behavioral intention (BI) to protect the environment.

This aligns with the theory that perceived social pressures, including the expectations of significant others, play a significant role in shaping intentions [42]. A study by Sheeran [53] supports this, demonstrating that subjective norms significantly influence environmental intentions.

1.1.3 Hypothesis 3 (H3)

Roadrunner's perceive behavioral control (PBC) towards protecting the environment positively influences their behavioral intention (BI) to protect the environment.

According to Ajzen [42], the perception of one's ability to perform a behavior significantly affects their intention to do so. Armitage and Conner [55] provide empirical support, showing that perceived ease of recycling is linked to stronger recycling intentions.

1.1.4 Hypothesis 4 (H4)

Roadrunner's perceive behavioral control (PBC) towards protecting the environment positively influences their behavior (BE) to protect the environment.

This hypothesis is based on the assertion that individuals are more likely to perform a behavior if they believe they have control over it [42]. Manstead and Parker [56] found that perceived behavioral control could directly predict behavior, supporting this hypothesis.

1.1.5 Hypothesis 5 (H5)

Roadrunners' behavioral intention (BI) towards protecting the environment positively influences their behavior (BE) to protect the environment.

This is consistent with the TPB, which posits that intention is the most immediate predictor of behavior [42]. Sheeran [53] provides evidence that intentions significantly predict actual behavior, especially in the context of environmental actions.

A research framework (Fig. 1) is developed for this study with the aim to address the above proposed hypotheses.

2 Methods

2.1 Study participants and procedure

This study was conducted from February to March 2021 through social media platforms and applications such as Facebook, Instagram, and LINE, distributing 443 self-administered online questionnaires. The design of the questionnaire required approximately 15 min to complete and was provided without any incentives. The target participants were Taiwanese road runners who had previous experience in road races and were aged 18 years or older. Announcements regarding the survey were posted on major road running groups' social media websites, and participants were encouraged to share the questionnaire within their networks. The questionnaire included five constructs, defined as per Table 13 and Table 14, with the Cronbach's alpha values detailed in Table.

A total of 430 valid questionnaire responses were received, of which males represented the majority (62.8%) with the remaining 37.2% being females. Most of the respondents were aged between 36 and 50 years old (47.9%) and 41.4% of them have a college academic qualification. Majority (38.8%) of the respondents had a monthly income of more than NT$60,000. Approximately 30.7% of the respondents had between 3 and 5 years of road race experience and most of them had participated between 1 and 3 road races (39.8%) in the year 2021. Findings also revealed that there were more respondents (59.5%) aware of the environmental protection road race as compared to those who were not (40.5%). A summary of the key descriptive findings is presented in Table 1.

2.2 Measurement tool

To ensure the content validity and contextual alignment of the questionnaire, a panel of three experts from the domains of forest conservation, environmental protection, and sports science have rigorously reviewed the questionnaire design. Their collective insights led to nuanced refinements in the questionnaire's wording, thereby enhancing its relevance to the specific nature of road-running events without compromising the original intent of the questions.

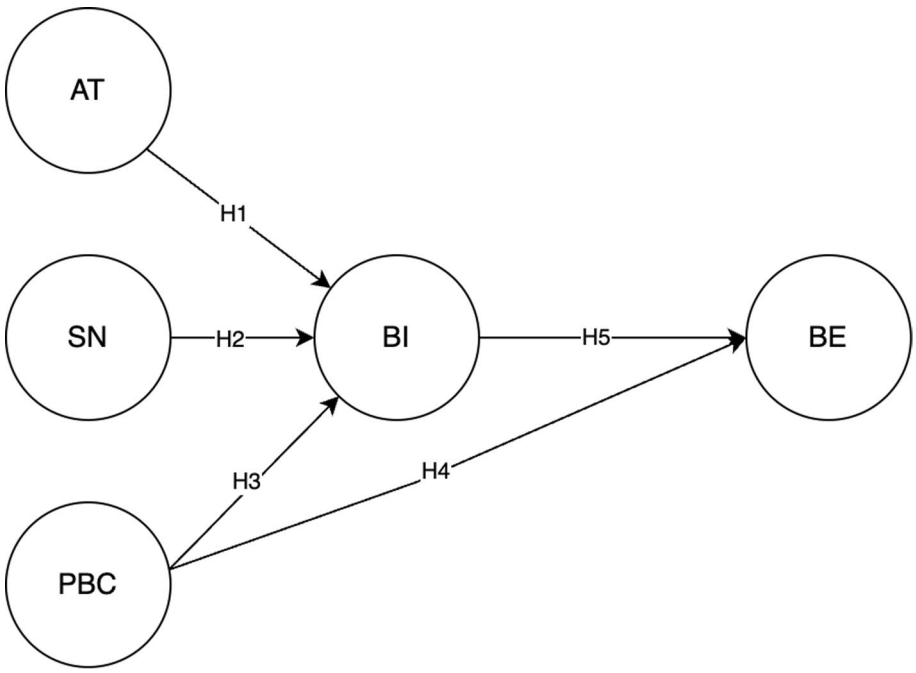

Fig. 1 Research framework (AT: attitudes, SN: subjective norms, PBC: perceived behavioral controls, BI: behavioral intentions, BE: Behavior)

Table 1 Descriptive statistic

Category	Variables	Frequency	%
Gender	Male	270	62.8
	Female	160	37.2
Age	18–19	3	0.7
	20–35	109	25.3
	36–50	206	47.9
	51–64	99	23.0
	Above 65	13	3.0
Academic Qualification	Junior High School or lower	5	1.2
	High School	53	12.3
	Junior College	50	11.6
	College	178	41.4
	Graduate School or above	144	33.5
Number of road races participated in the current year	None	11	2.6
	1–3 races	171	39.8
	3–5 races	104	24.2
	5–8 races	63	14.7
	8–10 races	31	7.2
	Over 10 races	50	11.6
Monthly income ($NTD)	Less than $25,000	42	9.8
	$25,000–$30,000	20	4.7
	$30,001–$35,000	36	8.4
	$35,001–$40,000	32	7.4
	$40,001–$45,000	48	11.2
	$45,001–$50,000	33	7.7
	$50,001–$55,000	26	6.0
	$55,001–$60,000	26	6.0
	Above $60,000	167	38.8
Heard of or know about the environmental protection road race	Yes	256	59.5
	No	174	40.5
Number of years of road race experience	Less than 1 year	23	5.3
	1–3 years	82	19.1
	3–5 years	132	30.7
	5–8 years	101	23.5
	8–10 years	28	6.5
	Over 10 years	64	14.9

2.3 Reliability and validity of the measurement tool

In this study, according to Table 2, the Cronbach's alpha values for all items exceeded 0.9, indicating a very high level of internal consistency and reliability. This further substantiates the accuracy and dependability of the measurement instruments used. No significant reliability issues were identified with any of the scales employed.

2.4 Data processing method

Our data collection instrument utilized a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), a range that allowed us to capture the intensity of participants' attitudes and perceptions effectively. Inclusion of a qualifying question, "Have you participated in any road-running events?" was essential to ascertain the

Table 2 Cronbach's alpha for all items in this study

A1	0.937
A2	0.935
A3	0.947
B4	0.935
B5	0.935
B6	0.937
B7	0.938
C8	0.936
C9	0.940
C10	0.942
C11	0.940
D12	0.935
D13	0.936
D14	0.938
E15	0.935
E16	0.936
E17	0.936
F18	0.937
F19	0.936
F20	0.937
F21	0.938
F22	0.935
F23	0.935
G24	0.935
G25	0.935
G26	0.936
G27	0.935
H28	0.937
H29	0.936

respondents' direct experience, thereby filtering out those without relevant exposure, which could potentially skew the study's findings. The subsequent descriptive statistics, specifically means and standard deviations (SD), provided a foundational understanding of the dataset, as they are crucial for elucidating patterns within the data that are pertinent to a broader population [57, 58]. The Pearson's correlation test was implemented using SPSS 26.0 software, to examine the relationships among the study variables. Furthermore, SMART-PLS 4 was utilized to analyze and confirm the applicability of the TPB model in this specific context, ensuring that the theoretical assumptions were consistent with the empirical data collected.

3 Results

3.1 Independent sample *t*-test

Analysis of the data revealed significant differences in several key variables related to environmental attitudes and behaviors. Specifically, females demonstrated superior performance across all assessed variables including Attitude (AT), Subjective Norms (SN), Perceived Behavioral Control (PBC), Behavioral Intention (BI), and Behaviors (BE), achieving higher mean scores and lower standard deviations compared to males, as detailed in Table 3. The differences in PBC, BI, and BE were statistically significant between genders.

According to Table 4, findings showed that respondents who have heard of the environmental protection road race had a higher mean score in all variables (i.e. AT, SN, PBC, BI, BE) than their counterparts who have not. However, there existed significant differences in two variables (AT, and SN) between these two groups.

Table 3 Gender independent sample *t*-test

Variable	Group	Mean	S.D	*t*	*df*	*p*
AT	Males	4.0079	0.66598	− 1.740	428	0.083
	Females	4.1205	0.61774			
SN	Males	3.8238	0.63996	− 1.445	428	0.149
	Females	3.9161	0.64056			
PBC	Males	3.9877	0.81302	− 2.203	428	0.028*
	Females	4.1632	0.77362			
BI	Males	3.9583	0.93610	− 3.045	384.464	0.002**
	Females	4.2125	0.77155			
BE	Males	4.1037	0.85887	− 2.989	428	0.003**
	Females	4.3479	0.74615			

* = $p < 0.05$
** = $p \leq 0.01$
*** = $p \leq 0.001$

Table 4 Independent sample t-test about environmental protection road race awareness

Variable	Response	Mean	S.D	*t*	*df*	*p*
AT	Yes (256)	4.1010	0.67108	1.987	428	0.048*
	No (174)	3.9745	0.61185			
SN	Yes (256)	3.9258	0.64324	2.673	428	0.008**
	No (174)	3.7586	0.62631			
PBC	Yes (256)	4.0855	0.80670	1.020	428	0.308
	No (174)	4.0051	0.79541			
BI	Yes (256)	4.0879	0.88788	0.993	428	0.321
	No (174)	4.0014	0.88358			
BE	Yes (256)	4.2487	0.81020	1.651	428	0.100
	No (174)	4.1149	0.84560			

* = $p < 0.05$
** = $p \leq 0.01$
*** = $p \leq 0.001$

3.2 Correlation analysis

Utilizing Pearson correlation coefficients, the analysis of data from respondents who participated in the road-running race demonstrated significant relationships between Attitude (AT), Subjective Norms (SN), Perceived Behavioral Control (PBC), Behavioral Intention (BI), and Behaviors (BE). These correlations ranged from moderate to high, as systematically cataloged in Table 5. The strength and direction of these relationships provide robust support for the study's theoretical framework, illustrating the interconnected dynamics of the psychological constructs under investigation.

3.3 Confirmatory factor analysis (CFA)

Factor loadings primarily measure the correlation between observed variables and constructs (Table 6). According to recommendations by [59], the factor loadings of observed variables must be significant and exceed a standard of 0.5. In the AT construct, items A1, A2, B4, B5, and B6 show strong explanatory power with loadings above 0.5, while A3 and B7 fall below, identifying A3 as a reverse-coded item. The SN construct also performs well with items C8, D12, and D13 exceeding 0.5, but C10, C11, C9, and D14 do not meet the standard. The PBC and BI constructs demonstrate robust explanatory strength across most items, except for F21 in the PBC construct slightly below 0.5. Lastly, the BE construct items H28, H29, and H30 all surpass the 0.5 threshold, confirming their strong explanatory power.

Table 5 Pearson's correlation coefficient

	AT	SN	PBC	BI	BE
AT	1.000				
SN	0.740***	1.000			
PBC	0.736***	0.735***	1.000		
BI	0.736***	0.683***	0.815**	1.000	
BE	0.693***	0.680***	0.776***	0.838***	1.000

** = $P \leq 0.01$

*** = $P \leq 0.001$

*** = $p < 0.001$—Two-tailed test

Table 6 Factor Loadings for Items within the Constructs AT, SN, PBC, BI, BE

Concept	Question	Factor Loadings (> 0.5)
AT	A1	0.658
	A2	0.740
	A3	− 0.127
	B4	0.782
	B5	0.809
	B6	0.689
	B7	0.466
SN	C10	0.126
	C11	0.215
	C8	0.747
	C9	0.283
	D12	0.792
	D13	0.719
	D14	0.478
PBC	E15	0.780
	E16	0.742
	E17	0.743
	F18	0.539
	F19	0.634
	F20	0.552
	F21	0.488
	F22	0.803
	F23	0.815
BI	G24	0.808
	G25	0.711
	G26	0.782
	G27	0.872
BE	H28	0.540
	H29	0.742
	H30	0.800

Source: [59]

3.4 Composite reliability, convergent validity, and discriminant validity

This study utilizes three metrics to assess the reliability and validity of the scales as shown in Table 7. Composite Reliability (CR) is employed to evaluate the internal consistency of the scales, with an ideal CR value exceeding 0.6

Table 7 Analysis of composite reliability and convergent validity

Concept	CR	AVE
AT	0.800	0.422
SN	0.696	0.296
PBC	0.887	0.473
BI	0.873	0.633
BE	0.741	0.494

[60]. Average Variance Extracted (AVE) measures the explanatory power of latent constructs over measured variables, indicating convergent validity if the AVE value surpasses 0.5[60]. The square root of AVE (SQRT(AVE)) is calculated to assess discriminant validity; a construct demonstrates discriminant validity when its SQRT(AVE) exceeds the absolute values of correlation coefficients with other latent constructs [61]. The results indicate that the Composite Reliability (CR) values for all five constructs are above 0.6, suggesting good internal consistency. Except for the BI construct, which meets the AVE standard, the remaining constructs do not meet the standard, as shown in Table 8.

3.5 Model fit assessment

The model's chi-square/degree of freedom ratio stands at 6.204, exceeding the ideal of less than 3, suggesting a complex model structure (Table 9). The Goodness-of-Fit Index (GFI) at 0.664 and the Root Mean Square Error of Approximation (RMSEA) at 0.110 both fall short of their respective thresholds of > 0.9 and < 0.08 [62, 63]. These results indicate areas where the model's fit could be enhanced. Similarly, incremental fit indices such as the Normed Fit Index (NFI), Tucker-Lewis Index (TLI), Comparative Fit Index (CFI), and Incremental Fit Index (IFI) all register below the optimal > 0.9, pointing towards potential improvements in these areas [62, 63]. However, the Parsimonious Comparative Fit Index (PCFI) and Parsimonious Normed Fit Index (PNFI) exceed the > 0.5 standard [64, 65], showing the model's efficiency and alignment with parsimonious requirements. While the model does not currently meet all recommended standards, these results offer a clear roadmap for future enhancements. By addressing the identified areas of improvement, we can refine the model's structure and performance, potentially achieving a higher degree of fit in subsequent iterations.

Table 8 Discriminant validity analysis

	AT	SN	PBC	BI	BE
AT	0.650				
SN	0.953	0.544			
PBC	0.870	0.872	0.688		
BI	0.905	0.894	0.927	0.795	
BE	0.913	0.921	0.967	1.041	0.703

Table 9 Model fit assessment

Category of Measurement Indices	Fit Indices	Data
Absolute Fit Indices	x^2/df	6.204
	GFI	0.664
	RMSEA	0.110
	RMR	0.103
Incremental Fit Indices	NFI	0.723
	TLI	0.731
	CFI	0.756
	IFI	0.757
Parsimony Goodness-of-Fit Tests	PCFI	0.686
	PNFI	0.656

Sources: [62–65]

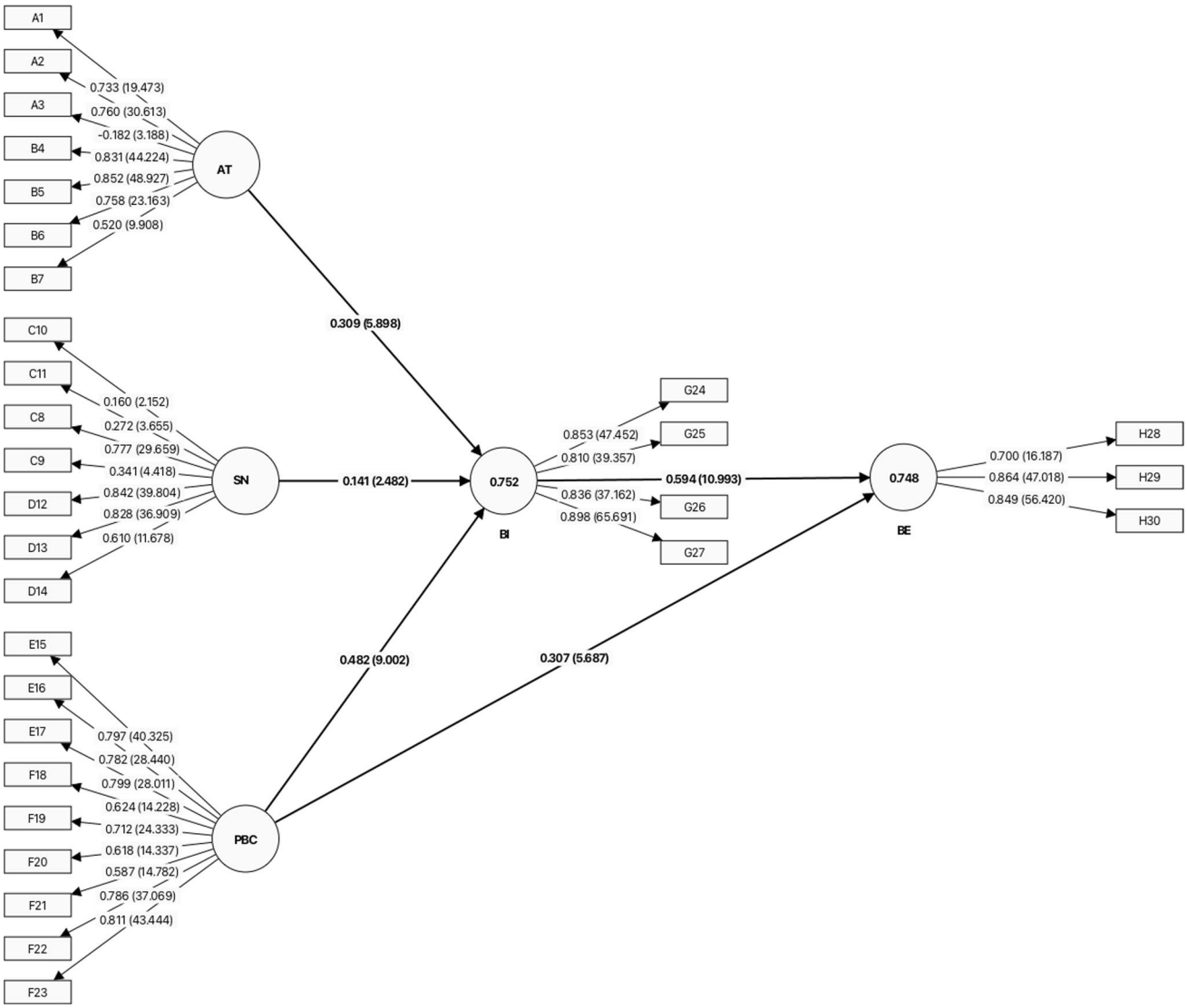

Fig. 2 Path coefficients of AT, SN, PBC, BI and BE

Table 10 TPB PLS-SEM analysis

	AVE	CR	R^2	Cronbach's α
AT	0.487	0.858		0.753
SN	0.369	0.809		0.662
PBC	0.531	0.900		0.888
BI	0.723	0.878	0.752	0.872
BE	0.652	0.757	0.748	0.732

3.6 Path analysis PLS-SEM

To evaluate the relationship between the PBT variables, we used the PLS-SEM technique, and confirmed the results using a bootstrapped *t*-value. Boot strapping is a test using random sampling and replacement, which mimics the sampling process. The method class analyzes the meaning of each path. According to the results of the PLS analysis (as shown in Fig. 2), this study applied the bootstrapping method of 5000 resampling to evaluate the PLS results. The reliability of the structure (as shown in Table 10) is evaluated using composite reliability (CR), and a CR value > 0.70

indicates good reliability. The Average Variance Extracted (AVE) evaluates convergent validity, and values > 0.50 demonstrate convergent validity.

3.7 SEM-PLS analysis of the TPB

According to Table 11, results showed all five direct path analysis had predictive positive effects AT → BI ($\beta = 0.309$, $t = 5.898$, $p < 0.001^{***}$), SN → BI ($\beta = 0.141$, $t = 2\ 0.482$, $p = 0.013^{*}$), PBC → BI ($\beta = 0.482$, $t = 9.002$, $p < 0.001^{***}$), BI → BE ($\beta = 0.594$, $t = 10.993$, $p < 0.001^{***}$), PBC → BE ($\beta = 0.307$, $t = 5.687$, $p < 0.001^{***}$). In addition, the analysis confirmed that behavioral intention (BI) serves as a mediator, facilitating the effects of Attitude (AT), Perceived Behavioral Control (PBC), and Subjective Norms (SN) on the actual Behavior (BE). Specifically, the paths AT → BI → BE, PBC → BI → BE, and SN → BI → BE were significant, demonstrating the mediating role of BI (AT → BI → BE: β = 0.184, $t = 5.067$, $p < 0.001$***; PBC → BI → BE: $\beta = 0.286$, $t = 7.843$, $p < 0.001$***; SN → BI → BE: $\beta = 0.084$, $t = 2.332$, $p = 0.02$*).

According to the f^2 indicator, the explanatory power of exogenous variables on endogenous variables can be assessed, making it a reference metric. Based on the evaluation criteria from [66] an f^2 value ranging from 0.02 to 0.15 indicates a small effect; an f^2 value between 0.15 and 0.35 signifies a medium effect; and an f^2 value greater than 0.35 represents a large effect [67]. Following this criterion, the f^2 value of "Behavioral Intention towards Behavioral Expectation (BI → BE)" in this study is 0.438, demonstrating a significant and substantial effect, which underscores the importance of behavioral intention in predicting behavioral expectations. The NFI (Normed Fit Index) metric evaluates the difference in chi-square values between the hypothesized model and the null hypothesis, with its value ranging between 0 and 1. According to the recommendation from Bentler and Nonett [68], the NFI value should exceed 0.9, with recent scholars suggesting 0.95 as a threshold for good fit [69]. Although the SRMR (Standardized Root Mean Square Residual) value in this study is 0.085, slightly above the 0.08 standard recommended by Hu and Bentler [69], this difference is minimal and remains within an acceptable range, indicating a relatively good fit of the model. Furthermore, the NFI value of 0.677, although below the 0.9 good fit standard defined by Bentler and Bonett [68], still provides a useful reference for the model's fit considering the study's aim to evaluate the predictive capability of the model.

4 Discussion

The primary objective of this study was to explore the environmental behaviors of road runners through the application of the TPB, with a particular focus on how attitudes, subjective norms, and perceived behavioral control influence behaviors. Our findings support Hypotheses H1-H5, confirming that road runners' attitudes towards environmental protection (AT), subjective norms (SN), and perceived behavioral control (PBC) positively influence their behavioral intentions (BI) to protect the environment. Furthermore, these behavioral intentions (BI) subsequently positively affect their actual environmental behaviors (BE). These results suggest that enhancing road runners' psychological motivations and societal pressures recognition can significantly increase their willingness and actions towards environmental conservation.

Table 11 Total effect and indirect effect-test of TPB

	β	Mean	STDEV	t	P value	f^2	Q^2	95% CI LL	95% CI UL	Model Fit
AT → BI → BE	0.184	0.182	0.036	5.067	< 0.001***			0.115	0.257	SRMR = 0.085
AT → BI	0.309	0.307	0.052	5.898	< 0.001***	0.112	0.452	0.207	0.412	NFI = 0.676
BI → BE	0.594	0.593	0.054	10.993	< 0.001***	0.438	0.462	0.484	0.694	Chi = 2864.790
PBC → BI → BE	0.286	0.284	0.036	7.843	< 0.001***			0.214	0.358	
PBC → BE	0.593	0.592	0.047	12.696	< 0.001***	0.117	0.414	0.206	0.416	
PBC → BI	0.482	0.48	0.054	9.002	< 0.001***	0.325	0.487	0.375	0.582	
SN → BI → BE	0.084	0.087	0.036	2.332	0.02*			0.021	0.162	
SN → BI	0.141	0.146	0.057	2.482	0.013*	0.025	0.403	0.036	0.263	

* = $P \le 0.05$

*** = $P \le 0.001$

4.1 Participants of older age show enhanced performance across TPB variables

The findings of this study elucidate that participants across different age brackets demonstrate environmental protection behaviors within the context of road-running events. A significant divergence in attitudes (AT), subjective norms (SN), perceived behavioral control (PBC), behavioral intention (BI), and behaviors (BE) was observed among participants of varying ages. These results allow us to infer that participants from distinct age groups exhibit variations in several variables associated with environmental protection behavior in road-running events. Notably, our analysis suggests that attitudinal dispositions toward environmental protection significantly vary across age groups, with individuals aged between 51 to 64 years displaying a markedly higher attitude (AT) compared to those in the 20 to 35 and 36 to 50 age cohorts, as unveiled through Post Hoc Tests utilizing Scheffe's Method for Multiple Comparisons (as indicated in Table 12). According to Hypothesis H1, roadrunners' attitude (AT) towards protecting the environment positively influences their behavioral intention (BI) to protect the environment. While the hypothesis did not explicitly postulate an interaction between age and attitude (AT), the findings indicate that the subjective norm (SN) and perceived behavioral control (PBC) among the 51 to 64 age groups significantly exceed those of younger groups, suggesting that age may enhance environmental consciousness and readiness to act. While the hypothesis did not explicitly postulate an interaction between age and attitude (AT), the findings indicate that the subjective norm (SN) and perceived behavioral control (PBC) among the 51 to 64 age groups significantly exceed those of younger groups, suggesting that age may enhance environmental consciousness and readiness to act. Similarly, the subjective norm (SN) and perceived behavioral control (PBC) among those within the 51 to 64 age groups were found to significantly surpass those of the younger groups, reinforcing the premise that environmental consciousness and the readiness to act are enhanced over time. These findings, resonating with prior research [70, 71], underscore a potential age-related paradigm shift in environmental attitudes and behaviors. The elevated behavioral intention (BI) and actual behavior (BE) within this demographic corroborate a critical aspect of our hypotheses, illustrating that the execution of environmental actions, alongside the willingness to undertake such actions, is significantly influenced by age. This interpretation extends beyond mere data representation, delineating a comprehensive narrative on the relationship between age and environmental stewardship, and underscores the imperative for targeted interventions that accommodate the diverse age demographics in fostering sustainable practices. The study's results reveal that older individuals exhibit more environmentally friendly consumption patterns in comparison to younger generations, detailed in Table 10. This pattern may not be solely attributed to financial capabilities; it could also signify a broader environmental wisdom that accrues with life experience.

Leisure activities that are environmentally and socially responsible have become pivotal for the tourism industry's growth [72]. The inclination towards "green" certified facilities is becoming increasingly prevalent, where operating in an environmentally friendly manner often entails higher investments and operational costs. Older runners, possessing more capital, are in a position to allocate more resources towards environmental protection, reflecting a commitment to sustainability that transcends mere participation in road-running events.

4.2 When females participate in road-running events, their PBC, BI, and BE for environmental protection are better than males'

This study observed that females consistently outperformed males across all measured variables of gender statistics in road-running events. Notably, females exhibited statistically significant higher scores in Perceived Behavioral Control (PBC), Behavioral Intention (BI), and Behavioral Engagement (BE) towards environmental conservation. These findings suggest that females not only perceive themselves as having greater control over their pro-environmental actions but also show a stronger intention to engage in such behaviors, which is further reflected in their higher levels of actual environmental engagement. The statistical significance of these differences was determined using [specific statistical tests], indicating a robust difference that warrants further investigation into the underlying factors contributing to these gender disparities in environmental attitudes and behaviors. According to role theory, different groups play different roles. For example, males and females exhibit different behaviors. Females are more likely than men to express environmental concerns and engage in environment-related behaviors (e.g., recycling, purchasing, eating organic food) [73, 74]. Due to traditional gender socialization, which often emphasizes the role of females as child-bearers, it has been suggested that females may be more inclined to adopt a worldview concerned with sustaining life and

relationships [75]. This protective mentality may extend to a more nurturing attitude towards nature. Consequently, it may be possible that females could exhibit higher attitudes and behaviors towards the environment than males, potentially starting with efforts within their local communities before expanding to the broader world [76].

The comparison with previous studies [77] underscores the significance of gender in environmental attitudes and behaviors. However, our study extends this narrative by specifically focusing on the road-running community, thus providing a nuanced understanding of how gender influences environmental protection behaviors within this demographic. This enriches the discourse on environmental psychology by illustrating the role of gender in shaping environmental stewardship in sports contexts.

The interpretation of our results further emphasizes the need to consider gender when designing environmental interventions and policies for road-running events. The findings suggest targeted strategies could be more effective if they leverage the inherent motivations and concerns of females. For example, fostering community involvement and highlighting the impact of environmental protection on future generations may resonate more strongly with female participants, potentially driving higher levels of participation in sustainability practices.

Additionally, the implications of this study extend beyond academic interest, offering practical insights for event organizers and policymakers. Understanding demographic-specific attitudes and behaviors allows for more effectively tailored interventions to encourage sustainable practices among road runners. This includes designing road-running events that minimize environmental impacts through waste reduction, promoting recycling, and encouraging the use of sustainable materials. The study's findings can also inform public awareness campaigns aimed at enhancing environmental engagement across the broader community, leveraging the influential role of female runners as advocates for sustainability.

In conclusion, our study contributes to the growing body of literature on environmental behaviors within the context of road-running, highlighting the critical role of gender differences. The detailed comparison with previous studies, alongside a thorough interpretation of our findings, underscores the need for gender-specific approaches to promoting environmental sustainability in sports events. This research not only enriches our understanding of the interplay between gender, environmental attitudes, and behaviors but also offers actionable insights for fostering a more sustainable road-running culture.

4.3 Runners who have heard or are aware of environmentally friendly road-running events perform better in AT and SN

The present investigation elucidates that individuals who are informed about environmentally friendly road-running events exhibit enhanced attitudes (AT) and subjective norms (SN) pertaining to environmental protection. This correlation was substantiated through a survey, where 256 respondents (59.5%) affirmed their awareness of such events, compared to 174 individuals (40.5%) who reported a lack of awareness. An independent sample t-test yielded results indicating a significant elevation in the AT scores amongst runners acquainted with environmental road-running events (as depicted in Table 4). These findings are in concordance with research delineated in Alonso-Vazquez [78] and Schwartz, Loewenstein and Agüero-Gaete [79]. Furthermore, physical sports events that promote environmentally friendly practices can positively influence their sports participants' purchasing behaviors for reusable and environmentally friendly products [80]. Engaging in environmentally conscientious behaviors, such as utilizing personal eco-friendly water containers, abstaining from collecting commemorative jerseys, curtailing the use of disposable plastic waste, and allocating registration fees to environmental conservation organizations, reflect emergent practices tied to environmental literacy and advocacy in the context of Taiwanese sporting events. Such behavioral adaptations are poised to positively influence public endorsement and proactive environmental stewardship within the domain of road-running, potentially extending to a broader spectrum of athletic endeavors.

4.4 Using TPB to investigate the routes of public participation in environmental protection behaviors during road-running events

The empirical results from the TPB path model robustly support the proposed hypotheses, illustrating a clear linkage between attitudes, subjective norms, perceived behavioral control, behavioral intentions, and environmental behaviors (Table 13). Specifically, the study confirms Hypothesis H1, as a strong positive relationship between runners' attitude (AT) towards environmental protection and their Behavioral Intention (BI) was evidenced ($\beta = 0.309$, $p < 0.001^{***}$). Hypothesis H2 is also supported, indicating that runners with favorable Subjective Norms (SN) towards environmental protection are more likely to develop a positive BI ($\beta = 0.141$, $p = 0.013^{*}$). Furthermore, a higher PBC significantly predicts a stronger

BI ($\beta = 0.482$, $p < 0.001^{***}$), affirming Hypothesis H3. These factors (i.e. AT, SN, and PBC) not only individually but also collectively contribute to forming the BI towards environmental actions. Hypothesis H5 is reinforced by the direct and substantial impact of BI on actual behavioral (BE) ($\beta = 0.594$, $p < 0.001^{***}$), underscoring the direct route from intention to action. The mediating role of BI in the relationship between AT, PBC, SN, and BE (AT → BI → BE: $\beta = 0.184$, PBC → BI → BE: $\beta = 0.286$, SN → BI → BE: $\beta = 0.084$, all $p < 0.05^{*}$) demonstrates the nuanced mechanism of how each component of the TPB model contributes to the environmental behaviors of runners. These findings are in harmony with the literature [81–84] and provide additional empirical support for the efficacy of the TPB model in predicting environmental behaviors [85].

The study's outcomes suggest that runners possess a commendable awareness of environmental preservation, with attitudes (AT), subjective norms (SN), and perceived behavioral control (PBC) influencing their behavioral intentions (BI), which in turn, instigate actual environmental behaviors (BE). The subjective norm is indicative of expectations from significant others, reflecting runners' anticipation of the opinions held by their esteemed peers [42].

The investigation's insights, drawn from participant responses at Taiwan's road-running events, unveil a discernible cognizance amongst attendees regarding the salience of eco-friendly practices within the domain of road-running. The findings highlight robust support for sustainable practices, indicative of a proclivity towards minimizing environmental impacts through the reduction of superfluous race souvenirs. Participants' self-initiated eco-friendly actions, such as bringing personal eco-friendly water receptacles, underscore a proactive environmental ethos, independent of mandates or guidelines from event organizers.

The likelihood of participation in future events is significantly shaped by the extent of the environmental initiatives promoted by organizers, such as advocacy for environmental stewardship and efforts to reduce plastic waste. This study has found that participants are likely to support and engage in events that prioritize sustainability, aligning their actions with the environmental objectives set forth by the organizers. Moreover, while regulatory measures by governing bodies or event organizers ensure compliance, the study reveals that participants themselves demonstrate a strong commitment to environmental conservation. This commitment is apparent in their readiness to adopt eco-friendly practices, suggesting that participants may not solely depend on regulations to guide their environmental responsibility. Instead, they are proactive in their efforts to reduce waste, indicating a shift towards a more self-directed approach to environmental stewardship in road-running events. Event organizers and policy makers, therefore, have the opportunity to further this momentum by facilitating and reinforcing a framework that supports and recognizes participants' eco-friendly initiatives.

4.5 Limitations

The study is limited to a single annual cross-sectional survey and may not capture the entire social, economic, and environmental spectrum of road-running events. Moreover, the survey was performed on runners from Taiwan only. A more global survey may shed important insight on our recreational impacts on the environment. Follow-up research and surveys are required if a deeper understanding is wanted, especially in light of the global issues we are faced with daily. Environmental education and knowledge influence pro-environmental behaviors. The questions can include subjective and objective knowledge or what people believe they know and what they actually know. Qualitative and quantitative research can be used in tandem to broaden the scope of the study nationwide and target indicator figures such as heads of large-scale road-running organizers, coaches of well-known running groups, people who have participated in road-running events, people who have not participated in road-running events, and heads of sports brand companies to conduct in-depth interviews. In-depth interviews can examine the concepts, current situation, methods, teachings of road-running promoters regarding implementing plastic reduction and environmental protection during road-running. Current situations, methods, teaching styles can be used to collect data from quantitative research using in-depth interview method to interpret the roles in various fields. The structural model employed in this study exhibited low fit indices, indicating potential issues with the model's capacity to accurately represent the underlying data. This limitation suggests that the research findings should be interpreted with caution and points to the need for considering alternative models or variables in future research.

5 Conclusions

The primary goal of this study is to use the TPB model to investigate the environmental protection behavioral factors of Taiwanese people participating in road-running events using the questionnaire survey as well as the SPSS and SEM-PLS analysis methods. Our findings underscore the necessity of integrating environmental protection interventions within

road-running events to foster greater public engagement and awareness. A positive disposition towards exercise, coupled with fewer perceived barriers and more favorable conditions, significantly enhances participation rates. Additionally, our research indicates that the environmental impact of road-running varies significantly with the locale—whether in mountainous regions, urban highways, or riverside paths—necessitating tailored strategies to mitigate negative outcomes and enhance sustainability. In this study, we adopted the TPB theory framework to analyze the environmental protection behavioral factors of people participating in road-running events. The results indicated that when females compete in road-running events, their perceived behavioral control, behavioral intention, and behavior regarding environmental protection are higher than those of males. Participants in road-running events who have heard of or are aware of environmentally friendly road-running events perform better in attitude and subjective norm variables. Older road-running event participants performed better on the various TPB variables.

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Author contributions CJP, BAL, EN, and WTF conceived the idea for the study, developed the conceptual framework, research methods and the survey. CJP designed and developed the project, executed and collected the data, and interpreted the results. CJP, BAL, EN, and WTF conducted the current analysis. CJP, BAL, EN, and WTF wrote the manuscript which was reviewed by all. All authors provided critical feedback and helped shape the research, analysis, and manuscript. All authors have read and agreed to the published version of the manuscript. All authors have approved the submitted version (and any substantially modified version that involves the author's contribution to the study); All authors have agreed both to be personally accountable for the author's own contributions and to ensure that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature.

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Data availability Data is provided within the manuscript or supplementary information files.

Declarations

Ethics approval and consent to participate According to the National Taiwan Normal University Research Ethics Committee, our research is not considered within the scope of the Human Subjects Research Act. Thus, the committee approved the study protocol (201707HS001) by National Taiwan Normal University and agreed that an informed consent was obtained when respondents complete the questionnaire. All methods were carried out in accordance with relevant guidelines and regulations approved by this Research Ethics Committee.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

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