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Mechanism of Water Use Behavior of College Students Based on the Improved TPB Model

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Abstract: Colleges and universities are a typical service water consumers in China, i.e., with a dense population, single structure, and regular water use. This means it is crucial to strengthen the management of their water use behavior. In this paper, first of all, the main water devices and water use behavior of students were elucidated by investigating and analyzing the structure and scenarios of water use in colleges and universities. Then, a model of water use behavior of college students with sociodemographic and environmental characteristics was constructed based on the theory of planned behavior (TPB). By investigating and analyzing the water use behavior, the theoretical judgment of the improved TPB model that "behavior is the result of interaction between individual and environmental characteristics" was proved, which provides a reference for studying the water demand requirements of college students and supports scientific water-use management in colleges, our results also help the exploration of potential water-saving solutions in order to construct water-conservative colleges and universities.

Keywords: colleges and universities; college students; water use behavior; TPB

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1. Introduction

China is a country that has historically had many people and little water. This means that water conservation is an important measure to maintain water security. In China, water is mainly used in agricultural, industrial, domestic, and other areas, among which domestic demand is the major consumer, which is increasing year by year along with people's demand for a better life. Colleges and universities, which integrate teaching, scientific research, and life, are also where domestic water use is concentrated. The size of colleges and the number of students are increasing annually with the development of education in China. Statistics from 1995 showed that 2.906 million students were enrolled in higher education [1]. In the past 30 years, the society has developed rapidly, colleges and universities have expanded enrollment, and the number of students has increased rapidly. Statistics from 2020 show that there were 2738 general institutions of higher learning throughout the country [2], with a total number of 41.83 million students, a 14-fold increase over the number of 1995, accounting for about 3% of the national population. In recent years, the total amount of domestic water consumption has been growing slowly, and the per capita water resources have therefore declined. Taking Beijing as an example, the data of the 2021 Beijing Statistical Yearbook showed that the domestic water consumption of Beijing in 2020 was 1.7 billion cubic meters, and the data in 2001 showed 1.2 billion cubic meters. Therefore, domestic water consumption is growing steadily. In terms of per capita water resources data, the per capita water resources of Beijing in 2020 were 11.7 billion cubic meters, and 139 cubic meters in 2001. In terms of water consumption in colleges and universities, the per capita water consumption in 106 colleges and universities under the direct ministries and commissions was 66 cubic meters per person in 2015 and 51 cubic meters per person in 2021, showing a decrease. Water-saving management in colleges and universities has an important impact on the development of urban water-saving. China has always attached importance to water-saving initiatives at colleges and universities. In addition to the application of water-saving products (water-saving devices, intelligent water cards, reclaimed water reuse, rainwater utilization, etc.), conservative water use behavior is also very important. Therefore, as the water users in colleges and universities, students' water use behavior and characteristics have an important role in promoting water conservation in colleges and universities.

At present, water-saving research on college students mainly includes predicting water consumption trends, simulating water consumption, providing water-saving measures, and optimizing water system designs. Li [3] built a model based on game theory, analyzed school water regulation and students' water-saving behavior strategies, predicted water consumption trends, and built a water-saving management and control platform. Yin [4] conducted a simulation study on the use of centralized domestic hot water by college students and simulated the hot water use data of the students in the specified water period, which provided a reference for the design and optimization of the hot water system in colleges and universities. Zhang [5] used a BP neural network algorithm to establish a daily water consumption prediction model for college dormitories, which laid a foundation for the subsequent prediction and analysis of sewage heat energy and also provided a reference for the comprehensive utilization of water resources in colleges and universities. The aforementioned studies mainly analyzed water saving from the perspective of students' overall water consumption behavior, while students' different water consumption behaviors have not been analyzed. In this paper, the mechanism of students' water consumption behavior is studied in order to provide a reference for research on water saving in colleges and universities.

The water use behavior of college students refers to their water use during studying on campus, showing their individual habits and styles. The different types of domestic water use include drinking, washing, flushing, showering, laundry, etc. The main water-consuming areas in colleges and universities are teaching buildings, office buildings, libraries, laboratory buildings (areas), sports venues, heating and cooling, dormitories, bathrooms, canteens, greening, etc., [6,7]. The proportion of water consumption in a college shows that the dormitory consumes as much as 44% of the total water used, followed by bathrooms, which consume as much as 12%. The water devices and products used in these are faucets, toilets, showers, washing machines, etc., which correspond to water use behaviors in regards to washing, drinking, flushing, shower, laundry, and so on. Relevant research shows that [8] flushing (16%), washing (13%), showering (36%), and laundry (18%) account for a large proportion of daily water consumption and are the main water-use behaviors of residents. The daily water consumption of the students was similar to that of the residents. Hence, these four behaviors of water use were investigated and analyzed in this study.

This study aimed to systematically analyze students' water use behaviors, covering their main water use behavior and analyzing their rules of water use behavior. This paper innovatively proposes a mechanism model for the university students' water use behavior and performs model verification. The analysis methods and conclusions of this study can provide guidance and reference for students' water use behavior management.

2. Methods and Materials

2.1. Construction of the Theoretical Model

According to the TPB in social psychology, attitudes, subjective norms, and perceived behavioral constraints interact to generate behavioral intentions, which in turn form environmental behaviors. One of the main points of TPB is that individuals and social and cultural factors (such as personality, intelligence, experience, age, gender, cultural background, etc.) indirectly affect behavioral attitudes, subjective norms, and perceived behavioral controls through influencing behavioral beliefs, and ultimately affect behavioral intentions and behaviors [9].

Chen LS [10] conducted research on the energy consumption behavior of urban residents and the residents' energy consumption behavior (including water). Its influencing factors were screened, and the influence and function of various factors on residents' energy consumption behavior were determined based on TPB and other theoretical methods. The results show that human characteristics and context structure factors can predict energy consumption behavior, and the TPB theory provides help for energy consumption behavior research. Lin Boqiang [11] through the theory of planned behavior model, explored the intrinsic family motivation that affected residents' willingness to use green electronic devices. By extending the planning behavior model theory, the impact of policy instruments on residents' willingness to use green energy was explored, and the analysis results of the TPB theoretical model provided theoretical support for the formulation of green power-related policies in China. Lou [12] introduced recycling convenience into the theory of planned behavior (TPB) in order to verify the influence of recycling convenience on user behavior and established the beneficial and significant influence of perceived behavioral control and behavioral intention on the recycling behavior of e-bike users. The results show that the extended theoretical framework of planned behavior is suitable for the study of e-bicycle user behavior. Nekmahmud [13] proposed a new model to assess consumer green purchase intention (GPI) through social media (SM) by extending the theory of planned behavior (TPB) to add variables such as green thinking, social media use, and social media marketing. It can be seen from the aforementioned studies that TPB theory is widely used in various fields and has achieved good results in consumer behavior such as residential energy resources. Because of the similarity between college students' water use behavior and residents' energy consumption behavior, the authors of this study believe that college students' water use behavior can be analyzed based on the TPB model in combination with influencing factors.

Zhu [14] discussed the direct influence of social demographic characteristics on college students' water-saving behavior; Cradock [15] studied the water supply situation on campus according to social demographic characteristics; Maria [16] analyzed the relationship between water-saving behavior and environmental problems; Andrew [17] analyzed the relationship between social demographic characteristics, attitudes, and water and energy use behaviors; and Isaac [18] analyzed the relationship between social demographic characteristics and social driving factors of household personnel's water use behaviors. The aforementioned studies have shown that students' or residents' domestic water use behavior is affected by their socio-demographic characteristics (gender, age, education level, etc.) and environmental characteristics (region, climate and season, education, rewards and punishments, etc.), so an analysis model can be built upon these socio-demographic and environmental factors in order to analyze the water use behavior of college students.

Based on the realities of water use in colleges, demographic and environmental characteristics were selected as influencing factors. College students in China have a similar gender distribution, mainly undergraduates and postgraduates between 18 and 24 years of age. As the small age gap that can be indirectly reflected in education level, gender (male and female) and education level (undergraduate and postgraduate) were selected as socio-demographic influencing factors. Colleges and universities are widely distributed throughout the country. Affected by the monsoon climate, water resources are unevenly distributed; thus, the region (north and south) can be used as the environmental influencing factors. In addition, the hot and sweaty summers result in greater water demand for showers compared to winters; therefore, the season can be used as another environmental influencing factor. In short, region and season are two environmental factors that influence the water use behavior of college students. On this footing, an innovative and improved TPB analysis model was proposed based on sociodemographic characteristics (gender and education level) and environmental characteristics (region and season), in line with the water use behavior of Chinese college students. The framework of the model is illustrated in Figure 1.

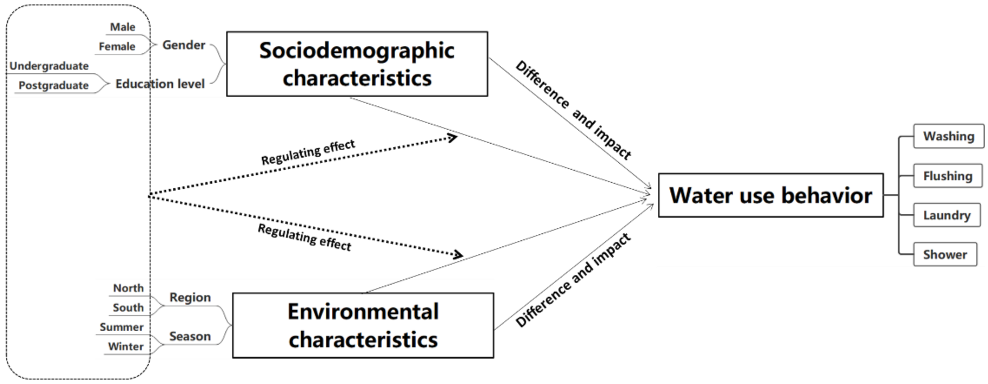


Figure 1. Analysis model framework of the influencing factors of college students' water use behavior.

In this paper, the model was constructed in order to assess:

(a) Whether sociodemographic characteristics and environmental characteristics have a significant difference with water use behavior;
(b) Sociodemographic and environmental characteristics have different degrees of influence on water use behavior, and whether there is a certain correlation between the degree of influence of factors and the degree of difference;
(c) Does one influencing factor regulate the impact of other factors on water use behavior if both sociodemographic and environmental characteristics have a significant difference with a certain water use behavior?

2.2. Questionnaire Design and Analysis Method

In this study, the data of students' water use behavior were obtained by using a questionnaire. The data included the daily washing time, daily flushing and daily shower frequency, and weekly laundry frequency. Reasonable values or intervals were selected as questionnaire options for the frequency and duration of the particular water use behavior. Students from colleges and universities across the country were selected as research subjects, and the questionnaires were distributed online and offline. The elements of the questionnaire are shown in Table 1. As a result, the amount of feedback for washing and flushing behavior was 311 (including 136 males and 175 females; 277 northern and 34 southern students; 224 undergraduates, and 87 postgraduates); laundry feedback was 277 (including 113 males and 164 females; 248 northern and 29 southern students; 200 undergraduates and 77 postgraduates); and shower feedback was 322 (including 143 males and 179 females; 286 northern and 36 southern students; 231 undergraduates and 91 postgraduates; 249 in summer and 73 in winter). The amount of feedback met the requirements of the model analysis. Model validation analysis was performed according to the questionnaire feedback water use behavior value (or interval mean).

In this study, multivariate analysis of variance was used to judge the difference of influencing factors on water use behavior. Multivariate analysis of variance is one of the methods of difference analysis, which is used to study whether a dependent variable is affected by multiple independent variables (also known as factors). It tests whether there are significant differences between the mean values of dependent variables among different combinations of multiple factor value levels. The existence of main effect was determined according to the multivariate variance results. The principle of analysis is to calculate F statistics and carry out F test. F statistic is the ratio of the average sum of squares between groups to the average sum of squares within groups. If the significance p value is <0.05, the level is significant and has a significant effect on the level, and there is a main effect.

Table 1. Elements of questionnaire on water use behavior of college students.

Elements	**Sociodemographic Characteristics**		**Environmental Characteristics**		**Water Use Behavior**			
	Gender	**Education Level**	**Region**	**Season**	**Daily Washing Time**	**Daily Flushing Frequency**	**Weekly Laundry Frequency**	**Daily Shower**
options	male	undergraduate	north	summer	0–60 s	3 times	0 times	0.25 times
	female	postgraduate	south	winter	60–120 s	4–6 times	0.5 times	0.33 times
	—	—	—	—	120–180 s	7–8 times	1 times	0.5 times
	—	—	—	—	180–240 s	9–10 times	2 times	1 times
	—	—	—	—	240–300 s	—	3 times	2 times
	—	—	—	—	—	—	4 times	—

In this study, the multilayer perceptron (MLP) model was used to judge the impact of influencing factors on water use behavior. MLP are often used to analyze the importance of variables [19,20]. As an algorithm model based on a neural network, MLP consists of an input layer, an output layer, and one or more hidden layers [21], as shown in Figure 2. The construction of the MLP model can be divided into forward propagation and backward propagation, in which the former calculates the output of neurons through the network structure and the weights and thresholds of the previous iteration, whereas the latter is used for parameter training, which is the process of calculating the influence of each weight and threshold on the total error from the output layer forward, and then adjusting the weights and thresholds in order to minimize the size of the error [22].

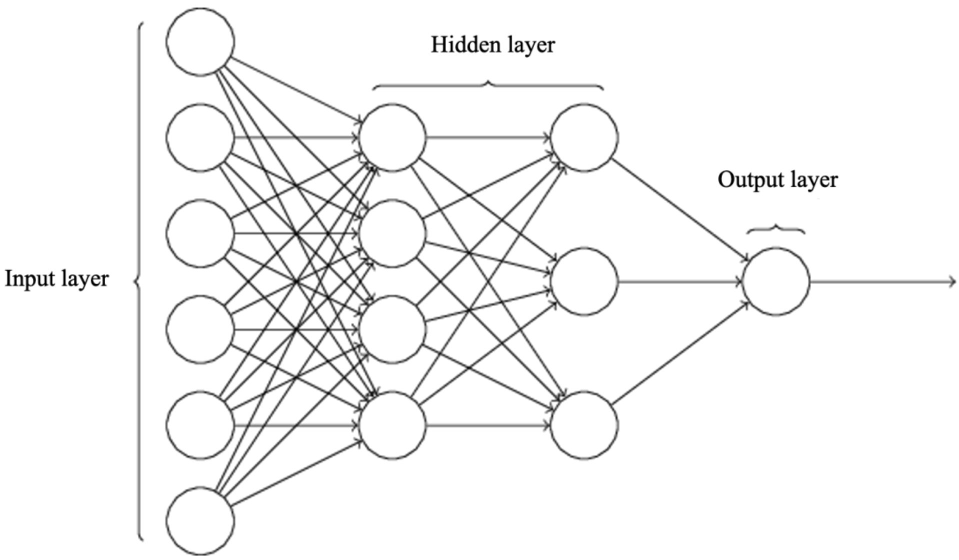


Figure 2. MLP model structure.

In this model, the learning process was completed by constantly adjusting the weight value w until the output value was consistent with the actual output value of the training samples. The formula for the weight value adjustment is as follows:

$$w_j^{k+1} = w_j^k + \beta\left(y_i - \hat{y}_i^k\right)x_{ij} \quad (1)$$

where w_j^k refers to the weight value of the j-th input link after the k-th cycle and β is the learning efficiency.

x_{ij} is the j-th attribute value of the i-th training sample;

$y - \hat{y}$ is the deviation of the predicted value from the actual value. When $y - \hat{y}$ is greater than 0, the weight value of all positive chains is increased to increase the predicted value of the output. When $y - \hat{y}$ is smaller than 0, the weight value of the positive chain is decreased, and the weight value of the negative connection is increased in order to decrease the predicted value of the output [23].

Receiver operating characteristic (ROC) curve was used to assess the accuracy of the model prediction by drawing the sensitivity (1 specificity) of the classification test. ROC curves were obtained by taking the actual water use behaviors of the sample individuals as the criterion to judge the optimal solution point, and the probability of the sample individual classification results given by the model as the judgment basis for the classification. The area under the curve (AUC) was greater than 0.5, which indicates that the model fitting is effective. The larger the AUC, the better the predictive ability of the model.

In this study, the regulation effect of any one variable on others was also analyzed for water use behavior, which means that one or several regulating variables play(s) a regulating role between the dependent and independent variables, so that the influence effect of the independent variables on dependent variables changes. Unlike mediating variables, the regulation effect refers to the study of when and how much M can play a role in the relationship X > M > Y. The regulation effect analysis table contains three model information. For model 1, the purpose is to study the influence of independent variable X on dependent variable Y without considering the interference of adjustment variable M. For Model 2: The adjustment variable M is mainly added to Model 2 on the basis of model 1. For model 3: the interactive product term of independent variable and regulating variable is added to Model 3 on the basis of model 2. Check whether the F value presents significant change from model 2 to model 3 or check whether the interaction item in model 3 presents significance (whichever is the item). If the change is significant, it means that there is a regulation effect.

3. Results and Discussion

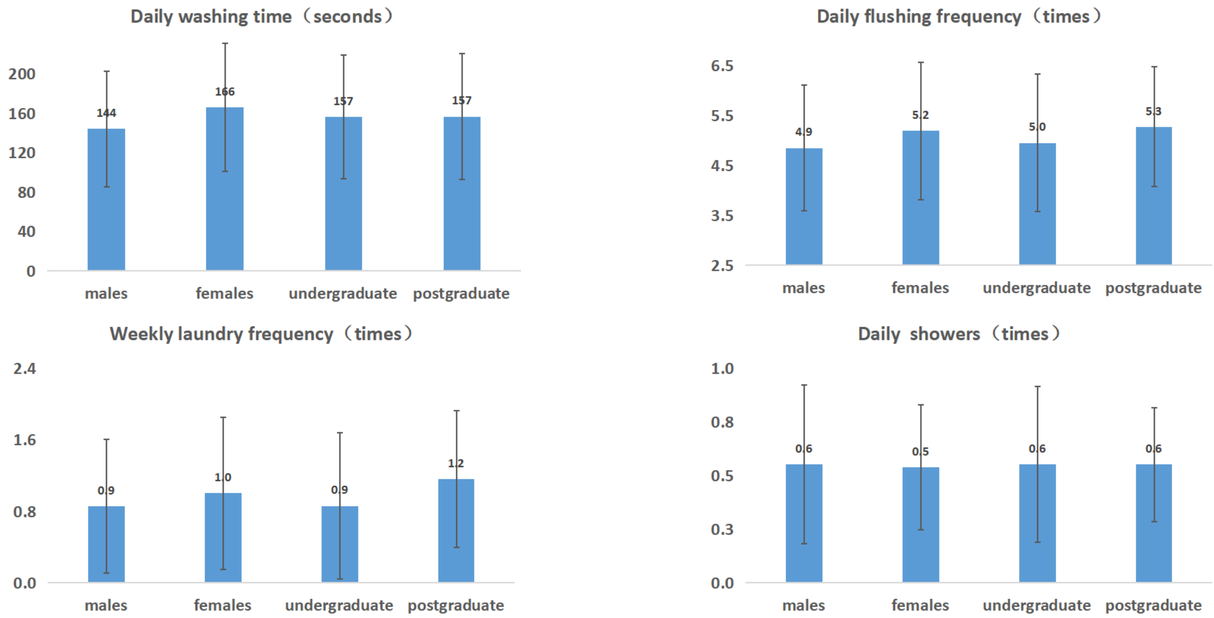
3.1. Results of Difference Analysis

Based on SPSSPRO, multi-factor contrast analysis was conducted on daily washing time, daily flushing frequency, weekly laundry frequency, and daily showers. The analysis factors were gender, region, education level, and season. The results are shown in Table 2. There are significant differences in daily washing time between different genders and different regions, significant differences in daily washing times between different genders, significant differences in weekly laundry times between different educational levels of students, and significant differences in bathing times between different regions and different seasons. Figure 3 shows the average level of water use behavior (including standard deviation) under different scenarios (socio-demographic characteristics and environmental characteristics), and provides data support for the difference analysis in Table 2.

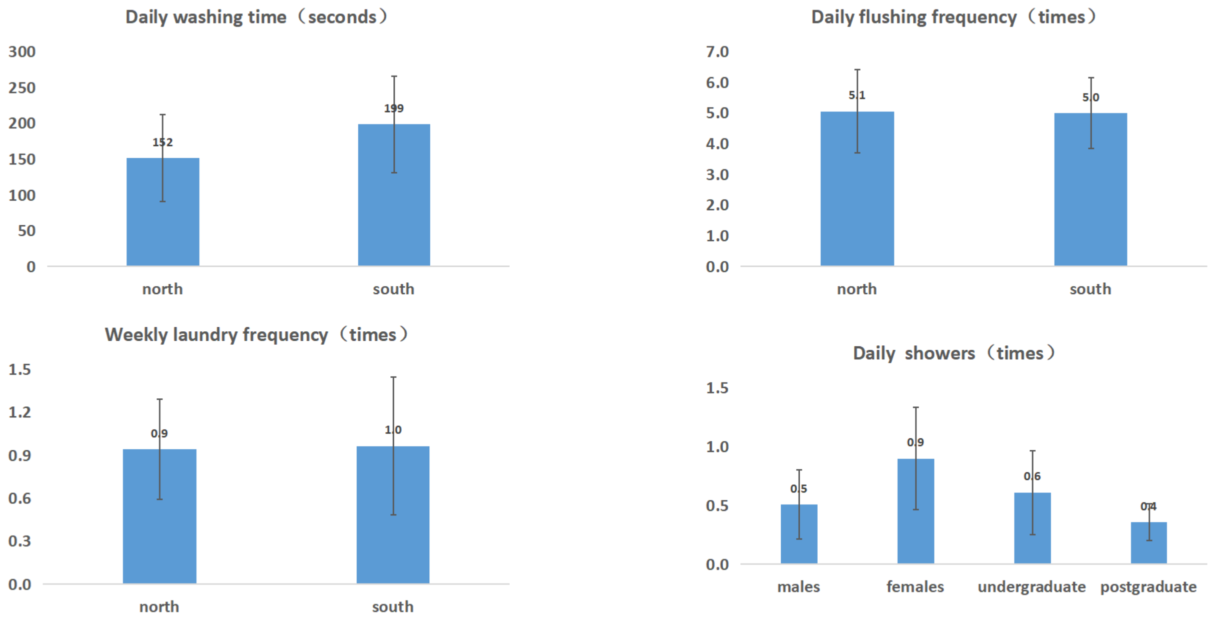
Table 2. Analysis results of difference between water use behavior and influencing factors (*p*-values).

Water Devices/ Products	Water Use Behaviors	Influencing Factors			
		Gender	Region	Education Level	Season
Faucets	Daily washing time	0.001 ***	0.000 ***	0.467	—
Toilets	Daily flushing frequency	0.031 **	0.695	0.061 *	—
Washing machines	Weekly laundry frequency	0.182	0.860	0.007 ***	—
Showers	Daily showers	0.758	0.000 ***	0.898	0.000 ***

Note: ***, ** and * represent 1%, 5%, and 10% respectively.



(**a**) Comparison of water use behavior under sociodemographic factors



(**b**) Comparison of water use behavior in different scenarios

Figure 3. Comparison of different water use behavior under different influencing factors.

3.2. The Results of Impact Analysis

The water use behavior of the students studied was taken as the criterion for determining the optimal solution point and the probability of classification results in the model as the basis for judgment, and receiver operating characteristic (ROC) curves were obtained. The area under each curve was greater than 0.5, indicating that the fitting is effective. The MLP model can be used to analyze the significance of gender, region, education level and season on water use behavior. The significance of four factors in water use behavior was analyzed based on the MLP model, as shown in Table 3.

Table 3. Comparison of factors' significance in water use behaviors.

Behavior	Item	Gender	Region	Education Level	Season
Daily washing time	Significance	0.267	0.581	0.152	-
	Normalization importance	45.9%	100%	26.2%	-
Daily flushing frequency	Significance	0.264	0.239	0.497	-
	Normalization importance	53.2%	48%	100%	-
Daily laundry frequency	Significance	0.324	0.306	0.369	-
	Normalization importance	87.9%	83%	100%	-
Daily showers	Significance	0.073	0.296	0.079	0.552
	Normalization importance	13.3%	53.5%	14.3%	100%

3.3. The Results of Regulating Effect Analysis

The difference analysis showed that there were two significant difference factors among daily washing time and amount of showering. Thus, SPSSPRO was used to analyze the regulatory effects of the two factors on water use behavior to determine whether there was a significant interference. Then, the region was taken as the variable to analyze whether it played a role between gender and daily washing time, the season as the variable to analyze whether it played a role in daily showers in different regions. See Tables 4 and 5 for the results of this analysis.

Table 4. Regulating effect analysis of the factors in the daily washing time.

	Model 1				Model 2				Model 3			
	Coefficient	**Standard Error**	***t***	***p***	**Coefficient**	**Standard Error**	***t***	***p***	**Coefficient**	**Standard Error**	***t***	***p***
const	122.158	11.729	10.415	0.000 ***	66.117	17.102	3.866	0.000 ***	55.11	41.026	1.343	0.180
Gender	22.107	7.154	3.09	0.002 ***	48.611	11.06	4.395	0.000 ***	30.731	25.589	1.201	0.231
Region					23.461	6.958	3.372	0.001 ***	58.475	35.197	1.661	0.098 *
Gender × region									−6.542	22.156	−0.295	0.768
ΔF	ΔF(1, 311) = 9.549, p = 0.002 ***				ΔF(1, 308) = 19.316, p = 0.000 ***				ΔF(1, 307) = 14.759, p = 0.000 ***			
Dependent variable: daily washing time												

Note: *** and * represent 1% and 10% respectively.

Table 5. Regulating effect analysis of factors in daily shower time.

	Model 1				Model 2				Model 3			
	Coefficient	**Standard Error**	***t***	***p***	**Coefficient**	**Standard Error**	***t***	***p***	**Coefficient**	**Standard Error**	***t***	***p***
const	0.119	0.065	1.843	0.066 *	0.431	0.081	5.348	0.000 ***	0.142	0.197	0.72	0.472
Region	0.389	0.056	6.962	0.000 ***	−0.239	0.04	−5.978	0.000 ***	0.637	0.173	3.684	0.000 ***
Season					0.373	0.053	7.017	0.000 ***	0.006	0.158	0.037	0.971
Region × season									−0.225	0.14	−1.604	0.110
ΔF	ΔF(1, 322) = 48.476, p = 0.000 ***				ΔF(1, 319) = 35.736, p = 0.000 ***				ΔF(1, 318) = 47.529, p = 0.000 ***			
Dependent variable: Frequency of daily shower												

Note: *** and * represent 1% and 10% respectively.

In Tables 4 and 5, the results of the regulating effect analysis table are shown, including Model 1, Model 2, and Model 3, as well as the standard error, *t*-test results, and significance

p-value of each model. The variables of the three models were analyzed and elaborated. The significance of Models 1 and 2 is relatively small. Model 3 is the core model, which includes interaction terms based on model 2.

The results in Table 4 of the regulating effect analysis showed that the p-value of ΔF value was 0.000 *** < 0.05 in models 2 to 3, indicating that the regulating variable region would significantly interfere with the influence of gender on daily washing time.

The results in Table 5 of the regulating effect analysis showed that the p-value of ΔF value was 0.000 *** < 0.05 in models 2 to 3, indicating that the regulating variable season would significantly interfere with the influence of region on daily shower time.

3.4. Discussion

The hypothesis of this study is that the sociodemographic and environmental characteristics have a significant difference with the water use behavior, but not with every type of water use behavior. The difference analysis results showed that the gender only had a significant difference between washing and flushing; female students' washing time and flushing frequency were higher than those of male students, and the same was true for washing and flushing demand. These results are consistent with those reported by Shi et al. [24]. Only washing and showering were significantly different with the regions. The washing time and frequency of showers in the south were higher than those in the north. The higher water demand for students in the south was mainly due to the large climate difference; the north is usually dry, cold in winter, and sultry in summer, while the south is relatively damp and humid all year round. As a result, the demand for washing and showering for students in the south was higher. The urban per capita daily water consumption obtained from public sources also showed that the south was generally higher than that in the north, which is consistent with the conclusion of this study. Education level only had a significant correlation with flushing and laundry. Postgraduate students were more frequent in flushing and doing laundry than undergraduates, probably because of their heavy research tasks, which saves time but consumes more water. Seasons only had significant correlation with the amount of showering. The frequency of showers in summer was higher than that in winter, with an average temperature of 18–28 °C, and the demand for showers increased in summer.

The hypothesis was shown to be correct in that sociodemographic and environmental characteristics have different impacts on water use behavior, and the degree of influence is related to the degree of difference. The results of the impact analysis showed that the daily washing time was most affected by the region, followed by gender; the most influential factor in the daily flushing frequency was education level, followed by gender; the most influential factor in weekly laundry frequency was education level, followed by gender; and the most influential factor in daily shower frequency was season, followed by region. Based on the results of the correlation analysis, the most influential factors also have a significant correlation with water use behavior.

The hypothesis is true that one influencing factor can regulate the influence of others on water use behavior if both sociodemographic and environmental characteristics have a significant difference with a certain water use behavior. The results of the regulating effect analysis showed that region as a regulating variable would significantly interfere with the effect of gender on the daily washing time; and season with the effect of region on daily shower frequency.

From the above discussion, it can be seen that the improved TPB analysis model based on the characteristics of college students' water use behavior in this study is valid, and the TPB model is also suitable for water use behavior analysis. Sociodemographic characteristics and environmental characteristics are important analytical factors of students' water use behavior, which have significant difference with students' water use behavior and have different degrees of influence, and the analysis factors can have a regulating effect.

4. Conclusions

In this study, the factors influencing students' water use behavior were selected based on the sociodemographic and environmental characteristics from the perspective of behavior and sociology, and a set of influencing factors was proposed. Subsequently, an analysis model of influencing factors was constructed based on the TPB theory and the water use scenarios of college students in China. The hypotheses were verified through questionnaire analysis. It is concluded that the college students' water use behavior is the result of the interaction between sociodemographic and environmental characteristics. The analysis results of college students' water use behavior characteristics in this study can be used for water use information management in schools. Based on the reference values of water use behavior of students for different genders, different education levels, different regions, and different seasons, combined with the other data (i.e., number of students in the school, gender composition, the proportion of students with different education levels, the region where the school is located, different seasons, and other data), the value of student water use behavior can be estimated. Moreover, the water demand can be estimated by combining the water consumption of water appliances corresponding to water use behavior.

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