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Investigation the Relation between Sleep and Quality of Life for College Students in Taiwan by Association Rule Mining

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Abstract: Background and objectives: Quality of life and sleep quality of college students were extensively studied. The present study evaluated sleep quality and quality of life of college students in Taiwan by using the Pittsburgh Sleep Quality Index (PSQI) and Short-Form Health Survey (SF-36), respectively. Materials and Methods: Data of 1756 college students aged 20–24 years were collected in this study. Association rule analysis was also used to provide a graphics-based visualization of the relationships between data, enabling the rapid identification of data correlations. Results: The results showed that the average physical component scale (PCS) and average mental component scale (MCS) scores were 52.9 and 44.1, respectively. Based on their body mass index (BMI), participants were divided into underweight, normal, overweight, and obese groups. The results of one-way analysis of variance showed that the p values for the PSQI, PCS, and MCS scores were 3.5×10^{-5}, 1.7×10^{-5}, and 0.671, respectively. The normal and overweight groups had the lowest PSQI scores. The PCS score of the obese group was lower than that of normal and overweight groups. The p values of the t-test result among PSQI, BMI, PCS, and MCS groups were 0.002, $<2 \times 10^{-16}$, and $<2 \times 10^{-16}$, respectively. The good sleep quality group had higher PCS and MCS scores. Conclusions: In this study, the results of association rule analysis indicated two distinct groups: Group 1, with the characteristics of good sleep quality as revealed by the high MCS and PCS scores, and Group 2, with the characteristics of poor sleep quality as revealed by low MCS and PCS scores and underweight BMI.

Keywords: association rule analysis; sleep; quality of life; college student

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1. Introduction

The advent of modern technologies and the fast-paced lifestyle have led to an increased prevalence of sleep disorders. More than 25% of people in Taiwan have been reported to be affected by insomnia [1]. Similar to air, food, and water, sleep is a necessity of life. Moreover, it is one of the fundamental requirements for physiological well-being, because sleep deprivation and poor sleep quality can substantially affect behavioral cognition and can cause other physiological changes. Long-term insomnia has also been found to increase the risk of emotional disorder; moreover, several studies have identified the correlations between insomnia or sleep deprivation and numerous psychological and physiological diseases [2]. Because sleep constitutes approximately one-third of a person's lifetime, sleep-related problems affect not only physiological and mental health but also the

development of interpersonal relationships and the performance of social functions. Thus, sleep disorder is a complicated problem that involves a wide range of aspects, including but not limited to personal, hereditary, physiological, psychological, mental, genealogical, social, and environmental factors [3]. Without adequate treatment or improvement, sleep disorder may result in serious mental and social problems. Sleep is closely related to physical and mental health problems as well as problem behaviors among adolescents and young adults [4]. In recent years, sleep quality has been widely used as a key indicator in the assessment of sleep in both clinical practice and medical research. However, few studies explore the concept. Sleep quality is highly complicated and thus difficult to define or measure objectively [5,6]. It is influenced by a number of factors, such as social transition, occupational stress, lifestyle, personal mental/health conditions, habits, the environment, diseases, and other physiological conditions [7]. As a basic requirement for health, sleep maintained with high quality is crucial in modern life [8]. Studies have indicated that a high percentage of young people lack quality sleep [9,10], which results in deteriorated academic and athletic performance and even leads to emotional and behavioral problems that eventually develop into mental diseases such as depression.

Advances in technology and social transition have led to a deferred sleep time, the consequences of which are insufficient sleep and poor sleep quality. These phenomena are becoming rapidly prevalent among people. For school-going youths, sleep disorder is often aggravated by study-related stress and electronic media abuse. Because adolescence is the pivotal period for mental and physical development, the influence of sleep cannot be overlooked. Improved sleep quality is known to be beneficial for mental and physical development, academic performance, and personality development. For youths, a lack of sleep or poor sleep quality can lead to fatigue, inattention, and increased daytime dozing, and poor sleep quality also affects their emotional conditions and behaviors in the long term. Furthermore, as they grow older, the situation of deferred sleep becomes more prominent among school-going youths, reducing their duration of sleep; compared with youths in the west, deferred sleep is more acute among youths in Asia [11]. The implication of the present study may be that college students must be made aware of the consequences of inadequate sleep quality and risk factors could be improved if students tried to change their behavior and subjective consciousness [12]. Other than the influence on behaviors, sleep disorder can also cause problems such as developmental retardation and obesity [13]. In addition, insufficient sleep syndrome is known to be associated with suicidal tendencies; youths with long-term sleep deprivation have been demonstrated to exhibit a higher risk of suicide than peers without sleep disorder [14]. Sleep not only controls the efficiency of initial learning but also mediates the subsequent consolidation of memory. During sleep, the biological activities of the neural system at molecular and cellular levels, as well as the remodeling mechanism of the neural network, exert strong effects on the consolidation of long-term memories [15]. Sleep is a requisite for the attainment, maintenance, and restoration of physical and mental health, including physiological function, cognition, and physical recovery [16]. Sleep is also essential for the sustainability of body functions; the cells damaged during the day are repaired during sleep, and the remodeling of cognition and memories in the brain occurs during sleep, which is the reason for higher mental alertness after sufficient sleep. Therefore, the quality of sleep achieved in the nighttime often influences the emotions and behaviors exhibited in the daytime [13]. Sleep is essential for the body, mind, memory, and learning [17]. A substantial portion of college athletes experience poor sleep health and would benefit from interventions aimed at improving sleep [18]. Furthermore, sleep quality has been shown to be closely associated with students' learning abilities and academic performance; poor learning capacity is often the related to constant sleep loss [19]. Students with poor sleep quality often exhibit poor mental clarity and academic performance in the day, and they are also more prone to depression and negative emotions [20].

Most recent studies on sleep quality have used the Pittsburgh Sleep Quality Index (PSQI) as the assessment tool for sleep quality [21]. The PSQI, which was developed by Buysse et al. [5], consists of seven items: subjective sleep quality, sleep latency

(i.e., the length of time required to fall asleep), sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. Each of these items is scored 0–3; a higher score denotes poorer sleep quality. The total score ranges from 0 to 21, and a total score of $\leq$5 indicates excellent sleep quality, whereas a total score of >5 implies poor sleep quality [22]. It is commonly known worldwide that lifestyle can influence personal health. The college stage is the pivotal period during which a youth grows into an adult, and this stage shapes his or her health-related behaviors. Applying assessment tools for college students' lifestyles and health-related behaviors can help them establish a healthy lifestyle and warn against unhealthy habits or factors. Consequently, adequate health-promoting strategies and interventions can be introduced to help them lead a healthy and positive life. Quality of life is an individual's perception of well-being in the cultural or value system he or she is in, and this perception is closely associated with personal goals, expectations, standards, and values. Lifestyle is a key factor that governs the life and health of modern people, and it is a key factor that influences the improvement in quality of life. Thus, a positive improvement in lifestyle will increase quality of life. Research has indicated that increased physical activities can lead to changes in lifestyle; thus, exercise is the most straightforward and effective strategy for improving quality of life [23]. Exercise is known to improve peoples' satisfaction with the physical, psychological, social, and environmental aspects of quality of life; although increasing physical activities can only rectify health-endangering behaviors, it can still improve quality of life [24]. In terms of health, people with intensive physical activities usually have higher quality of life than those who are inactive [25]. Regular physical activities have been proven to exert numerous positive effects that can improve the physiological system, physical fitness, cardiovascular function, immunity, endocrine system, cognitive function, and general health [26]. The positive effects of regular exercise on physical and mental health are positively correlated with life satisfaction. A healthier body and mind contribute to greater life satisfaction and hence higher quality of life.

The Short-Form Health Survey (SF-36) is a self-rated scale consisting of eight multi-item subscales plus one additional item for the perceived change in health [27,28]. The eight subscales can also be divided into two summary measures: the physical component scale (PCS), which combines physical function, role limitations due to physical health problems, bodily pain, and general health perceptions subscales, and the mental component scale (MCS), which combines vitality, social functioning, emotional well-being, and role limitations due to emotional problems subscales. As per the scoring instructions, the scores of these two scales are calculated as follows: the scores of the eight subscales are standardized; thereafter, the standardized scores of each subscale is multiplied by a standardized coefficient derived from factor analysis depending on the scale (PCS or MCS); subsequently, the scores of the same scale are summed up to provide the composite score. The score of each subscale ranges from 0 to 100, with 0 denoting the poorest quality of health and 100 the highest quality of health [29]. The SF-36 has been widely applied to evaluate quality of life, including that of college students [30].

The recent development of big data analytics has benefited studies investigating sleep quality and health. Schatz Bruce applied big data analytics techniques for mobile health monitors and showed that complete baseline records can be acquired by using effective National Surveys of Population Health [31]. Among the numerous big data analytics techniques, link analysis is an information science approach [32] that uses graphics-based visualization methods to present related data, enabling the rapid identification of correlations between the data [33]. Association rule analysis can also be integrated with text analysis; such integration has been proven to be effective for web document analysis [34]. In the present study, link analysis was implemented along with conventional statistical analysis to identify significant factors affecting college students' sleep quality and quality of life.

2. Materials and Methods

2.1. Participants Information

In this study, 1756 college students aged 20–24 years were recruited as participants. A total of 958 and 798 participants were men and women, respectively. Participants information is listed in Table 1.

Table 1. Participants information.

Group	Mean	Max	Min
Age	21.1	24.0	20.0
Height	168.0	198.0	146.0
Weight	61.6	120	37
BMI	21.7	40.3	13.8

2.2. Institutional Review Board Statement

Participants provided written consent and their demographic data. Subsequently, they completed the SF-36 and PSQI surveys. The study protocol was approved by the Institutional Review Board of Asia University (IRB approval No. 10512004).

2.3. Association Rule Analysis and STATISTICS

Assume there are two groups, and X is element in the first group, Y is element in the second group. There are three parameters used in association rule analysis [35] Support: The percentage of union of X and Y to the total number of the data, and m is the total number of the data.

$$support(X, Y) = \frac{X \cup Y}{m} \times 100\% \quad (1)$$

Confidence: The ratio of union of X and Y to the number of either X or Y.

$$confidence(X \Rightarrow Y) = \frac{X \cup Y}{X} \times 100\% \quad (2)$$

$$confidence(Y \Rightarrow X) = \frac{X \cup Y}{Y} \times 100\% \quad (3)$$

Lift: The ratio of confidence to expected confidence.

$$lift(X, Y) = \frac{support(X, Y)}{support(X) \times support(Y)} \quad (4)$$

The association rule analysis is conducted using PolyAnalyst 6 software (Megaputer Co. Bloomington, IN, USA). The categorized PSQI, PCS, and MCS scores of the BMI groups were imported to PolyAnalyst. A high significance between the variables could be demonstrated and visualized as a link pattern.

2.4. Statistical

Descriptive statistics were calculated for the means, standard deviations, quartiles, and numbers of participants' BMI, PSQI, PCS, and MCS data. One-way analysis of variance (ANOVA) was applied to evaluate the PCS, MCS, and PSQI data of the four BMI groups, followed by a t test for each group. Because PSQI scores were categorized into only two types ("good sleep quality" and "poor sleep quality"), a t test was applied to examine the differences in BMI, PCS, and MCS data between the PSQI groups. Additionally, a two-way chi-square test was applied to determine differences in the BMI, PSQI, PCS, and MCS data. To determine the R-squared value of the regression line, a regression analysis was implemented to examine the paired PCS, MCS, and PSQI data.

3. Results

The distributions of participants' BMI, PSQI, PCS, and MCS are shown in Figure 1a–d, respectively. The bar charts in the figure show that the BMI, PSQI, PCS, and MCS data were all evenly distributed. The quartiles of these data are listed in Table 2.

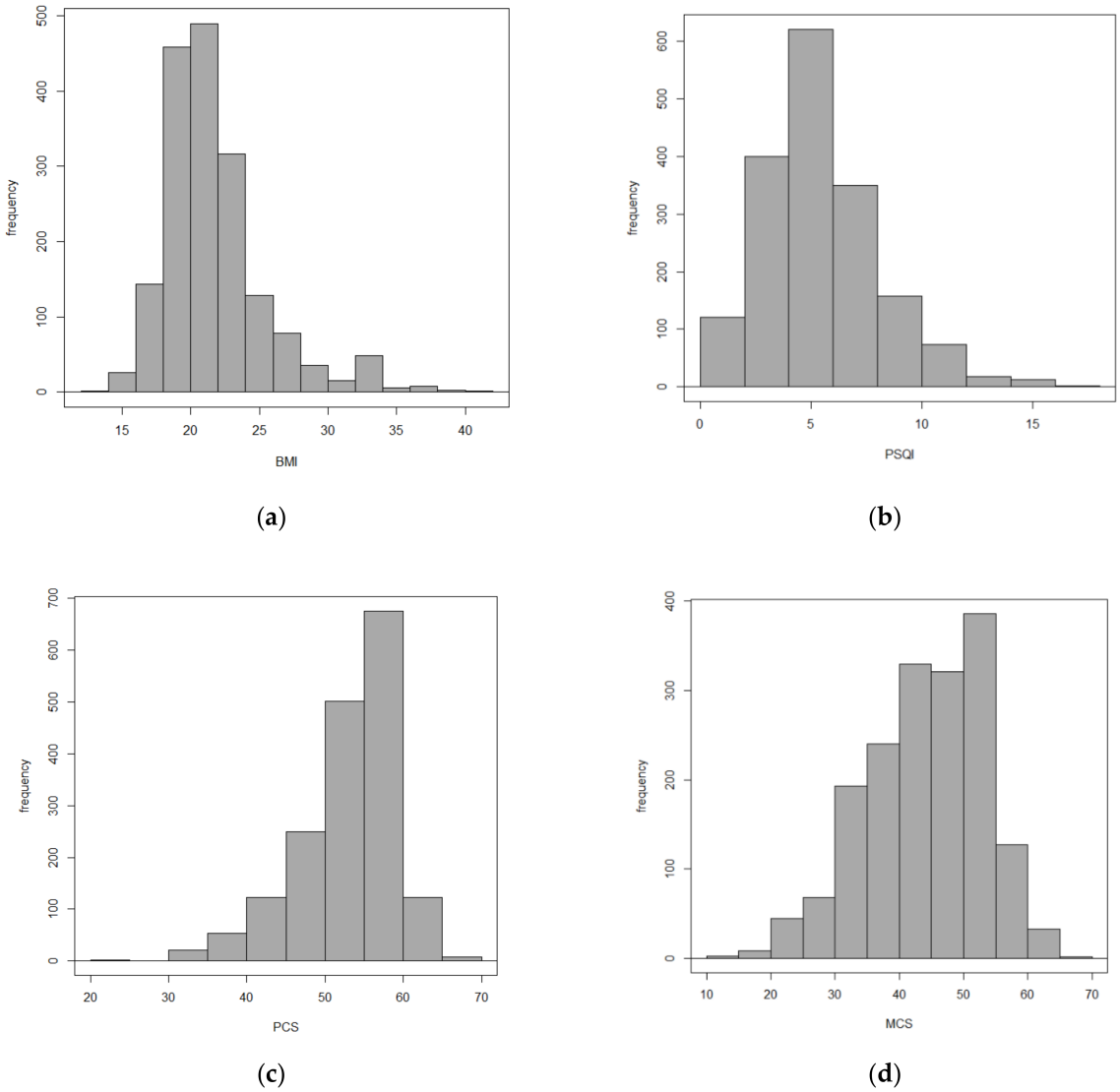


Figure 1. Distribution of (**a**) BMI, (**b**) PSQI, (**c**) PCS, and (**d**) MCS.

Table 2. Distribution of BMI, PSQI, PCS, MCS.

Group	Mean	SD	0%	25%	50%	75%	100%
BMI	21.7	3.8	13.8	19.4	20.9	23.0	40.3
PSQI	5.9	2.7	0	4	5	7	17
PCS	52.9	6.3	20.2	49.7	54.3	57.5	67.0
MCS	44.1	9.2	11.2	37.6	44.9	51.5	67.2

For PSQI, the mean score was 5. A score of 5 or higher indicated a diagnosis of sleep disorder. The mean PCS and MCS scores were 52.9 and 44.1, respectively. Subsequently, participants were divided into groups based on different parameters. For PSQI, participants with a PSQI score of $\geq$5 were classified as "good sleep quality" (N = 925), whereas those with a PSQI score of <5 were classified as "poor sleep quality" (N = 831). For PCS and MCS, participants were divided into two groups. Those with a PCS score of <50 were

classified as "PCS < 50" (N = 449), and "PCS > 50" group were 1307 subjects. Similarly, "MCS < 50" (N = 1208), and "MCS > 50" (N = 548) were also classified. Participants were divided into four groups based on their BMI: underweight "BMI < 18.5" (N = 238), normal "24 > BMI $\geq$ 18.5" (N = 1197), overweight "27 > BMI $\geq$ 24"(N = 165), and obese "BMI $\geq$ 27" (N = 156). The number of participants in the groups are listed in Table 3. The BMI definition of the four groups is according to the rule by Ministry of Health and Welfare in Taiwan [36].

Table 3. Number of participants in the groups.

Groups	Sub Groups	Subject Numbers (N)
BMI groups	Underweight "BMI < 18.5"	238
	Normal "24 > BMI $\geq$ 18.5"	1197
	Overweight "27 > BMI $\geq$ 24"	165
	Obese "BMI $\geq$ 27"	156
PSQI groups	Good sleep quality ($\geq$5)	925
	Poor sleep quality (<5)	831
PCS groups	PCS > 50	1307
	PCS < 50	449
MCS groups	MCS > 50	548
	MCS < 50	1208

Table 4 shows the results of one-way ANOVA for the PSQI, PCS, and MCS scores of the four BMI groups. Significant differences in PSQI, PCS, and MCS scores were observed among the four BMI groups. Moreover, the results of the paired t test showed that underweight and obese groups exhibited similar PSQI scores (b), with a mean PSQI score $\geq$ 6. By contrast, the normal and overweight groups exhibited the similar low PSQI scores, with a mean PSQI score of $\leq$5.7 (a). This finding suggests that both obesity and underweight have negative effects on sleep. The PCS score of the obese and underweight groups was significantly lower than normal and overweight groups. No statistical difference was observed in the MCS score among the BMI groups. This finding suggests that BMI is unrelated with the mental aspect of quality of life.

Table 4. One-way ANOVA results for BMI group. Superscript Letter a,b,c are label for the same group based on t-test result. The same lettern means the same group. *** denote p value < 0.001.

Group	Underweight (N = 238)	Normal (N = 1197)	Overweight (N = 165)	Obese (N = 156)	p Value
PSQI	6.5 (2.9) ^{b}	5.7 (2.5) ^{a}	5.9 (2.9) ^{ab}	6.4 (2.8) ^{b}	0.0000352 ***
PCS	52.0 (6.7) ^{ab}	53.4 (6.1) ^{c}	52.9 (7.1) ^{bc}	51.0 (6.5) ^{a}	0.0000172 ***
MCS	44.7 (9.9) ^{a}	43.9 (9.0) ^{a}	44.2 (10.2) ^{a}	44.2 (8.8) ^{a}	0.671

Table 5 shows the results of t test for the BMI, PCS, and MCS scores of the PSQI groups. The poor Sleep Quality group had lower PCS and MCS scores, whereas the PSQI_better group had higher PCS and MCS scores. This finding suggests that PSQI is highly correlated with PCS and MCS. However, the difference between PSQI and BMI was found to be nonsignificant.

Table 5. Results of t test for PSQI groups. *** denote p value < 0.001.

Group	Good Sleep Quality (N = 925)	Poor Sleep Quality (N = 831)	Pr (>F)
BMI	21.7 (3.6)	21.7 (3.9)	0.832
PCS	54.1 (5.5)	51.7 (6.9)	5.81×10^{-16} ***
MCS	46.4 (8.3)	41.4 (9.5)	$<2 \times 10^{-16}$ ***

Table 6 shows the results of the two-way chi-square test. A statistical difference was observed between the PSQI groups and PCS and MCS ($p < 10^{-16}$), corroborating the preceding results. Moreover, statistically significant differences were observed among the PSQI, PCS, MCS and BMI groups.

Table 6. Two-way factor analysis and *p* values.

Group	BMI	PSQI	PCS
BMI			
PSQI	0.002		
PCS	0.020	$<2.2 \times 10^{-16}$	
MCS	0.015	$<2.2 \times 10^{-16}$	2.956×10^{-12}

The results of link analysis clearly indicated the existence of two patterns (groups), which are shown in Figure 2, and their parameters are listed in Table 7.

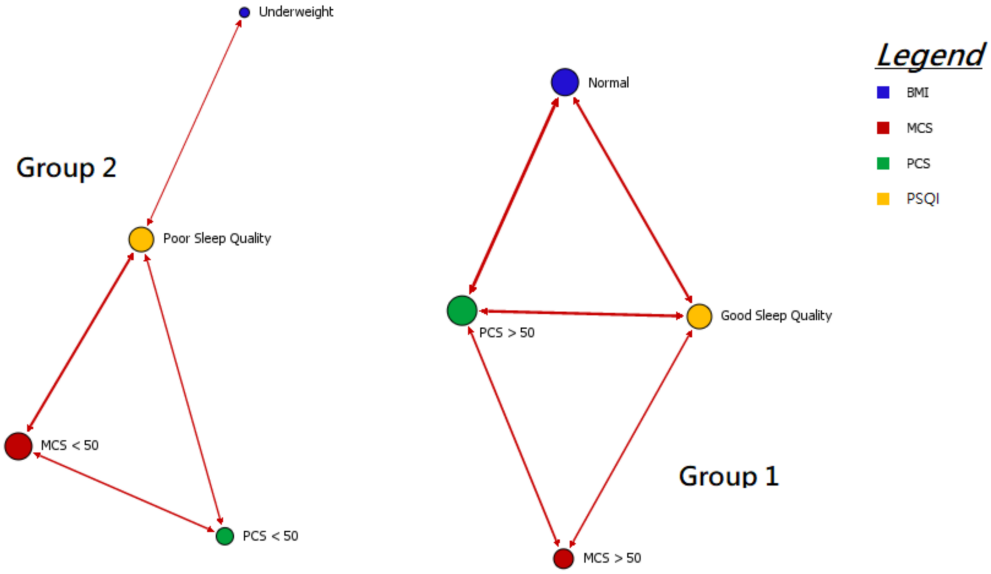


Figure 2. Links among high support parameters by association rule analysis.

Table 7. Association rule analysis result of two groups. Table 7a–d are result for union, support, confidence and lifting.

(a) Union results of two groups					
Group 1		Good Sleep Quality	PCS > 50	MCS > 50	Normal
	Good Sleep Quality	925	765	372	663
	PCS > 50	765	1307	467	917
	MCS > 50	372	467	548	
	Normal BMI	663	917		1197
Group 2		Poor Sleep Quality	PCS < 50	MCS < 50	Underweight
	Poor Sleep Quality	831	289	655	135
	PCS < 50	289	449	368	
	MCS < 50	655	368	1208	
	Underweight	135			238

Table 7. *Cont.*

(b) Support results of two groups. Support = Union/m, m = 1756.					
Group 1		PCS > 50	MCS > 50	Normal	
	Good Sleep Quality	43.6%	21.2%	37.8%	
	PCS > 50		26.6%	52.2%	
Group 2		PCS < 50	MCS < 50	Underweight	
	Poor Sleep Quality	16.5%	37.3%	7.7%	
	PCS < 50		21.0%		
(c) Confidence results of two groups.					
Group 1	Denominator	Good Sleep Quality	PCS>50	MCS>50	Normal
	Good Sleep Quality		82.7%	40.2%	71.7%
	PCS > 50	58.5%		28.5%	70.2%
	MCS > 50	67.9%	85.2%		
	Normal	55.4%	76.6%		
Group 2		Poor Sleep Quality	PCS<50	MCS<50	Underweight
	Poor Sleep Quality		34.8%	78.8%	16.2%
	PCS < 50	64.4%		82.0%	
	MCS < 50	54.2%	30.5%		
	Underweight	59.2%			
(d) Lifting results of two groups.					
Group 1		PCS > 50	MCS > 50	Normal	
	Good Sleep Quality	0.000632767	0.000733873	0.000598794	
	PCS > 50		0.00065202	0.000586138	
Group 2		PCS < 50	MCS < 50	Underweight	
	Poor Sleep Quality	0.000775	0.000652	0.000713	
	PCS < 50		0.000678		

4. Discussion

In this study, two groups were identified through the association rule analysis of the data. One group was the healthier group with the characteristics of good sleep quality, PCS > 50, MCS > 50 and normal BMI level. The other group was the group with poor quality of life and sleep quality, and PCS and MCS both less than 50. The average SF-36 score is 50. Thus, the healthier group had a higher-than-average PCS and MCS score, and the less healthy group had a below average PCS and MCS score, accompanied with underweight BMI level. Furthermore, this study proposed an interesting approach: association rule can be used for clustering statistical data. Each data batch contains numerous parameters; conventional statistical methods can only determine the existence of correlations or significant differences among the parameters, but these methods cannot identify the concurrent characteristics that the groups with parameters exhibiting significant difference possess. Moreover, for a large number of parameters, conventional statistical methods are time consuming for making one-by-one comparisons and still fail to provide a complete result. The association rule can link data batches with the same characteristics, and for a high number of links, a bold line will be shown as an indication. Moreover, association rule can rapidly visualize significant clusters among the data batches. This new approach, along

with the visualization effect, is much faster than conventional statistical approaches for sorting data. A high significance value also indicates a statistical difference. For example, in Group 1, the "good sleep quality" group was linked with PCS > 50, MCS > 50 and normal BMI group. In Group 2, the "poor sleep quality" group was linked with PCS < 50, MCS < 50 and underweight BMI group. According to the statistical test results, a statistical difference was observed between the sleep quality groups and the PCS groups and MCS groups ($p < 2.2 \times 10^{-16}$). Therefore, the visualized results of link analysis can provide not only enables the rapid clustering of data, but also identifies parameters with high statistical differences through the visualization of direct links. Another benefit of this approach is the fast computation time, which enables the rapid processing of massive amounts of data. However, for its effectiveness, highly significant clustering should be present in the data. Considering that association rule analysis has never been applied in this type of study, its successful application here can be considered a major contribution of this study.

Other commonly used data clustering methods, such as K-means clustering, require advance knowledge on the number of clusters or the distribution of data. However, these methods are ineffective when little difference is present in the data. Moreover, they are ineffective when little difference is present between data dimensions. For example, when the MCS and PCS data, which are of similar dimensions, were converted into an x-y two-dimensional distribution diagram (Figure 3), the two groups could not be distinguished from the diagram. Moreover, because the R-square of linear regression line was 0.0035, MCS and PCS were obviously not positively correlated. Thus, previously applied data analysis methods are unable to show any clearly distinguishable clustering patterns for the data, which is their limitation. Association rule analysis, however, can identify the distinction from the links of sample characteristics and can rapidly visualize the links, which is convenient.

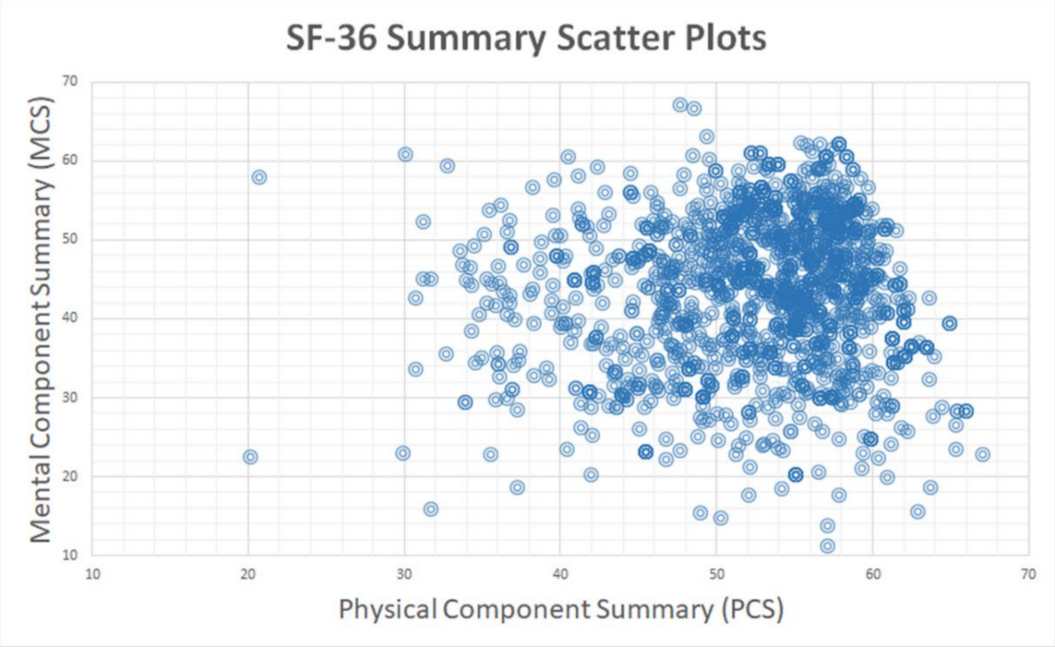


Figure 3. PCS-MCS distribution map.

There are several limitations to this article. In the data part, the data were only collected from single college school, and the amount of data is not very large. The more schools that can be collected, the better the correlation between the two questionnaires can be presented. In the method part, association rule analysis may be superior to the traditional clustering method, judging by the results of this study. This conclusion is only applied on the correlation between PSQI and Quality of life surveys. If it is applied to other questionnaires, it may not have similar results. More research is needed to verify.

In addition, the number of subjects needed to present for association rule analysis to cluster separate data which have no statistical difference is still unknown. This study can be treated as it a pilot study, indicating that association rule analysis may be applicable to the grouping of survey data.

The future direction of this study can be extended from several aspects. The first is to study the relation between two surveys from before and after a specific health promotion program. The association rule analysis results may reflect the improvement of sleep quality and quality of life for college students. The second is to increase the number of data in the set, including total subject numbers and college numbers to verify whether the findings of this study are present in other general college student populations. The third is to apply association rule analysis on other surveys, and to investigate the correlation between the degree of difference of the data and clustering performance by association rule analysis.

5. Conclusions

Although numerous studies have been conducted on quality of life and sleep quality of college students, the application of association rule analysis for the clustering and distribution of a massive sample data is innovative. In this study, this approach enabled the rapid grouping of participants into the healthier and less healthy groups, and then used graphics-based visualization to present the links between their quality of life and sleep quality scores. This is a rapid and effective approach for presenting data and preliminary analytic results.

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