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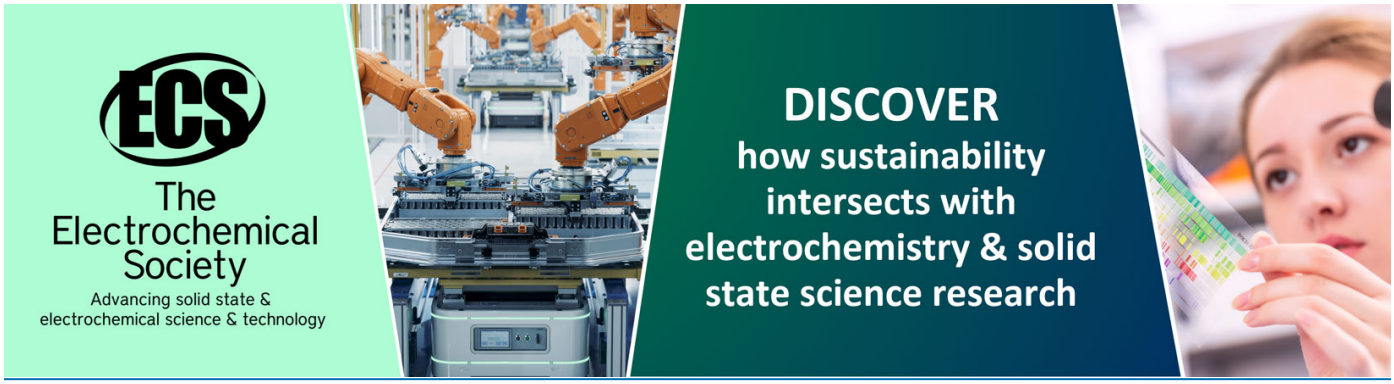

Chi-square analysis of people's knowledge of balanced diet and aerobic exercise at different stages of type 2 diabetes mellitus

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Abstract. Patients with Type 2 Diabetes Mellitus (T2DM) die every eight seconds in the world. T2DM is still not eradicated at home and abroad at present, thus "just control". A balanced diet and aerobic exercise (intervention treatment) can reduce risk factors and the incidence of diabetes and diabetic complications, which prevents or delays the onset and progression. The survey of people's knowledge of balanced diet and aerobic exercise has been conducted in Luzhou, Neijiang, Nanchong and Ziyang of Sichuan province and Tongren of Guizhou province from June to September 2019. A total of 865 subjects' questionnaires have been collected. Taking prediabetes as baseline, people's knowledge difference of balanced diet and aerobic exercise is compared forwards in low- or high-risk stage and backwards in the diabetes stage and diabetic complication stage through Pearson χ^2 test and the correlation coefficient Cramer's V and Φ. The knowledge difference in prediabetes and high-risk (χ^2=4.2996, p=0.0224, Cramer's Φ=0.1038) is statistically significant, and the difference in prediabetes and diabetic complications (χ^2=231.5272, p< 0.0000001, Cramer's Φ=0.5905) is also statistically significant. Knowledge of balanced diet and aerobic exercise at prediabetes stage is significantly higher than that in high-risk and that in diabetic complications. Doctors, nurses and researchers should use the Internet and door-to-door to educate people about the importance of balanced diet and aerobic exercise during prediabetes and diabetic complications in T2DM.

1. Introduction

It is from the ninth diabetes atlas of International Diabetes Federation estimated that China has more than 116 million diabetics by 2019 and has ranked first in the world since 2010 and that one dies of diabetes every eight seconds [1]. Diabetes mellitus is a group of etiologically heterogeneous metabolic diseases characterized by chronic hyperglycemia accompanied by carbohydrate, fat, and protein metabolism disorders. It is caused by defective insulin secretion and/or defective insulin action. Type 2 Diabetes Mellitus (T2DM) accounts for about 95%. From the natural history of T2DM, the progression stages are divided into low-risk, high-risk, prediabetes, diabetes, diabetic complications [2]. The term high-risk meets risk factors defined by World Health Organization; otherwise it is low-risk of diabetes. Blood glucose is normal at high-risk stage; however, it in prediabetes stage is higher than normal but lower than the level at which T2DM is diagnosed [3]. Diabetic complications [4], as important causes of disability, blindness and death, can occur within 3 to 10 years without the intervention treatment. Unfortunately, T2DM is still not eradicated at home and abroad at present, thus "just control" [5]. A balanced diet and aerobic exercise (walking, running, cycling, playing basketball, swimming and

climbing) reduce risk factors and the incidence of T2DM and diabetic complications, which prevents or delays the onset and progression [6-9]. Practice aerobic exercise during prediabetes, and incidence rate of T2DM is reduced by 43% from the medical research [10]. Balanced diet and aerobic exercise are the important measures for early intervention and treatment. In fact, only when the disease progresses to diabetes or diabetic complications, patients start balanced diet and aerobic exercise. Medically, T2DM should be early intervention treatment. Has the general population the knowledge that balanced diet and aerobic exercise can interfere with the occurrence and progression? At which stage do they practice balanced diet and balanced diet? Are there significant differences at different stages? For doctors, nurses and researchers, which group should be educated about the knowledge of the effects of balanced diet and aerobic exercise on T2DM? As far as we know, there are no relevant studies.

Table 1. Questionnaire knowledge of balanced diet and aerobic exercise for type 2 diabetes mellitus.

Item	Question options
Question1: Can a balanced diet interfere with type 2 diabetes mellitus (T2DM)?	Yes; No; I don't know
Question2: Can the aerobic exercise interfere with T2DM?	Yes; No; I don't know
Question3: At which stage do you do balanced diet and aerobic exercise?	LRD; HRD; Prediabetes; Diabetes; Diabetic complications

Low-Risk of Diabetes=LRD.
High-Risk of Diabetes=HRD.

Design questionnaire to investigate i) people's knowledge of effects of balanced diet and aerobic exercise on T2DM, and ii) at which stage do people practice balanced diet and aerobic exercise. It is noted that the more knowledge people have, they are more likely to engage in balanced diet and aerobic exercise. Only prediabetes can return to high-risk, after sticking to balanced diet and aerobic exercise for a long period, such as twenty years [10]. Subjects' balanced diet and aerobic exercise need to be followed up for a long time. Knowledge, action and ending are another topic, which is beyond the scope of this paper. The topic in this paper is people's knowledge of effects of balanced diet and aerobic exercise on T2DM.

It seems that three questions presented in the questionnaire are very simple, but it is indeed difficult to conduct the survey. The researchers have explained the effects of balanced diet and aerobic exercise on T2DM to the subjects who had no concept of balanced diet, aerobic exercise and T2DM. The explanation is part of the tasks for Question1 and Question2. The addition of new problems to represent this work is not reasonable. Diabetes status of the enrolled subjects has been identified as the progression stage, according to the physical examination report, diabetes screening and treatment in the medical institutions. In case that the subjects don't have the above evidences, they have been taken to the medical institutions for testing. This work, part of the task for Question3, has been done by the researchers in the projects listed in Acknowledgement. Similarly, the addition of new problems to represent this work is not reasonable.

Although the questionnaire looks simple, the designed questionnaire works in the survey. The survey has been conducted in Luzhou, Neijiang, Nanchong and Ziyang of Sichuan province and Tongren of Guizhou province from June to September 2019. Options of Question1 and Question2 are "Yes", "No", and "I don't know". For example, the surveyed subject answered "I don't know" for both balanced diet and aerobic exercise, suggesting that this subject had no knowledge of balanced diet and aerobic exercise. From the natural history of T2DM, the progression stages are divided into five progression stages including low-risk, high-risk, prediabetes, diabetes, diabetic complications, i.e., options of Question3. Only prediabetes can return to high-risk after a long period of balanced diet and aerobic exercise. Under investigation, however, definitely diabetes status of any subject occurs in one of the stages. It is clear at which stage the surveyed subjects had. All the subjects were able to choose their own

progression stages. All the questionnaires completed by the subjects are valid, and no invalid questionnaires are excluded.

Mentioned above, all the questionnaires completed by the subjects are valid, and no invalid questionnaires are excluded. A total of 865 subjects' questionnaires are collected. The survey data have been converted to Table 2 as the following steps.

i) The selection of "Yes" for both balanced diet (Question1) and aerobic exercise (Question2) is judged to be the right answers. The surveyed subjects answered “I don’t know” for both questions, suggesting that these subjects had no knowledge of the effects of balanced diet and aerobic exercise on T2DM. The reason for the answers “No” for both questions is that it doesn’t last long enough to achieve the effect of intervention and treatment. The rational for answers “No” or “I don’t know” for one of both questions is that either balanced diet or aerobic exercise works judging from their own experiences and the experiences of others around them. The wrong answers should indicate that people do not have comprehensive knowledge of the effects of balanced diet and aerobic exercise on T2DM, or do not know at all. Therefore, all but the answers “Yes” for both questions should be judged as the wrong ones.

ii) It is valid for the subjects to choose their own stages, one of five progression stages including low-risk, high-risk, prediabetes, diabetes, diabetic complications (Question3). Under investigation, definitely diabetes status of any subject occurs in one of stages. It is clear at which stage the surveyed subjects had, according to the physical examination report, diabetes screening and treatment in the medical institutions.

iii) The right and wrong answers have been categorized by each stage. The accuracies of the subjects at five stages have been calculated and shown in Table 2.

Table 2. Classification of people’s knowledge of balanced diet and aerobic exercise.

Stage	Right [a]	Wrong [b]	Total	Accuracy
LRD	80	20	100	80.0%
HRD	56	18	74	75.7%
Prediabetes [c]	278	47	325	85.5%
Diabetes [d]	22	5	27	81.5%
Diabetic complication [d]	91	248	339	26.8%
Total	527	338	865	60.9%

Low-Risk of Diabetes=LRD. High-Risk of Diabetes=HRD.

[a] Subjects choose "Yes" for question 1 and question 2 in Table 1.

[b] Subjects choose “No” or “I don’t know” for one of question 1 and Question 2 in Table 1, or for both questions.

[c] From the medical research, a balanced diet and aerobic exercise reduce risk factors and the incidence of diabetic complications, which prevents or delays the onset and progression.

[d] Only when the disease progresses to diabetes or diabetic complications, patients start balanced diet and aerobic exercise.

The accuracy of five stages of T2DM is only the result of the sample observation. Due to the sampling error, hypothesis testing is needed to get the conclusion of whether there is difference in accuracy or not. T2DM should medically be early intervention treatment; however, in fact only when the disease progresses to diabetes or diabetic complications, patients start balanced diet and aerobic exercise. To theoretically reveal the key population of diabetes education, it is very important to compare prediabetes stage with low-risk, high- risk, diabetes, and diabetic complications.

This problem belongs to nonparametric significance analysis. Non-parametric significance analysis methods include Pearson chi-squared test (χ^2 test) [11], rank sum test [12] and Ridit analysis [13]. The rank-sum test is to change the exact measured value into the sequential rank, which loses part of the information and causes test effectiveness to decline. The Ridit analysis can show which group is better and illustrate the extent of the difference between each comparison group. Rank sum test and Ridit analysis are not suitable for this problem.

2. Pearson χ^2 test

In 1900, the British statistician Karl Pearson introduced χ^2 test based on the theory of chi-square distribution and goodness of fit. Pearson χ^2 test is a hypothesis test method to investigate the difference between the sample frequency distribution and the theoretical frequency under the hypothesis. It is applied in homogeneity test, independent test and suitability test. The significance determined by χ^2 is related to the sample size. The section reviews independence test and the correlation coefficient Cramer's V and Φ.

2.1. Independence test

The contingency table is the statistical table that results in a bidirectional cross arrangement when observing the performance of each individual in relation to categories for the same set of objects. Suppose there are R groups in the contingency table, each group with C categories (Table 3). The entries in the table is actual frequency count A_{ij}, i=1,2,…,R, j=1,2,…,C. The edge sum of each row is $A_{i.}=\sum_{j=1}^{C} A_{ij}$ and the edge sum of each column is $A_{.j}=\sum_{i=1}^{R} A_{ij}$. The total amount is $n=\sum_{i=1}^{R} A_{i.}$ or $n=\sum_{j=1}^{C} A_{.j}$.

Table 3. R x C rows and columns contingency table.

Actual frequency	Category 1	Category 2	…	Category C	Total
Group 1	A_{11}	A_{12}	…	A_{1C}	$A_{1.}=\sum_{j=1}^{C} A_{1j}$
Group 2	A_{21}	A_{22}	…	A_{2C}	$A_{2.}=\sum_{j=1}^{C} A_{2j}$
...	…	…	…	…	…
Group R	A_{R1}	A_{R2}	…	A_{RC}	$A_{R.}=\sum_{j=1}^{C} A_{Rj}$
Total	$A_{.1}=\sum_{i=1}^{R} A_{i1}$	$A_{.2}=\sum_{i=1}^{R} A_{i2}$	…	$A_{.C}=\sum_{i=1}^{R} A_{iC}$	$n=\sum_{i=1}^{R} A_{i.}$

Under the assumption, the theoretical frequency (expected frequency) of each cell in Table 3 can be calculated, and is represented by the symbol T. The calculation of each element T_{ij} (Table 4) is given by formula (1) and Table 3.

$$\begin{cases} T_{ij} = \dfrac{A_{i.}A_{.j}}{n} \\ A_{i.} = \sum_{j=1}^{C} A_{ij} \\ A_{.j} = \sum_{i=1}^{R} A_{ij} \\ i = 1,2,\ldots,R,\ j = 1,2,\ldots,C \end{cases} \tag{1}$$

Table 4. The theoretical frequency.

	Category 1	Category 2	…	Category C
Group 1	T_{11}	T_{12}	…	T_{1C}
Group 2	T_{21}	T_{22}	…	T_{2C}
...	…	…	…	…
Group R	T_{R1}	T_{R2}	…	T_{RC}

The total amount n and the theoretical frequency T_{ij} (i=1,2,…,R, j=1,2,…,C) in Table 4 determine common χ^2 test, Yates' correction for continuity, or Fisher's exact test, as the following:

i) $n\geq 40$ and $T_{ij}\geq 1$. The larger the theoretical frequency T_{ij}, the distribution is closer to the chi-square distribution. When no more than 20% of T_{ij} is located at [1, 5), it agrees well with the chi-square distribution. Chi-square statistic is calculated by formula (2).

$$\begin{cases} \chi^2 = \sum_{i=1}^{R}\sum_{j=1}^{C}\frac{(A_{ij}-T_{ij})^2}{T_{ij}} \sim \chi^2(v) \\ v = (R-1)(C-1) \end{cases} \tag{2}$$

If more than 20% of T_{ij} is located at [1, 5), the right-hand side of formula (2) deviates greatly from the chi-square distribution. Chi-square statistic is calculated by Yates' correction for continuity.

$$\begin{cases} \chi^2 = \sum_{i=1}^{R}\sum_{j=1}^{C}\frac{(|A_{ij}-T_{ij}|-0.5)^2}{T_{ij}} \sim \chi^2(v) \\ v = (R-1)(C-1) \end{cases} \tag{3}$$

ii) n<40, or T_{ij}<1. Fisher's exact probability is calculated and used for the test.

Under the condition that hypothesis H_0 is true, the right-hand side of formula (2) and (3) obeys χ^2 distribution, and the degree of freedom v=(R-1)(C-1). According to the test level α, look up χ^2 distribution table (v), and get the critical value$\chi^2_{\alpha,v}$ in the rejection domain, then the decision criterion is as follows:

i) When $\chi^2 \geq \chi^2_{\alpha,v}$, reject H_0 and accept H_1.

ii) When $\chi^2 < \chi^2_{\alpha,v}$, accept H_0.

2.2. Correlation coefficient

From formula (2) or formula (3), the degree of freedom (v) has nothing to do with the sample size n. However χ^2 increases with n. Draw relevant conclusions only based on the significance of χ^2 value, which cause a problem. Rea L. M. and Parker R. A. have proposed the correlation coefficient Cramer's V and Φ for the association strength (Table 5) based on χ^2 in 1992. Cramer's V and Φ don't change with the sample size, and relevant research results need to report the correlation coefficient.

$$\begin{cases} V = \sqrt{\frac{\chi^2}{n(M-1)}}, M-1 \neq 1 \\ M = \min\{R, C\} \\ \phi = \sqrt{\frac{\chi^2}{n}}, M-1 = 1 \end{cases} \tag{4}$$

Tabel 5. Degree of association.

Cramer's V and Φ	The association strength
0.00-0.10	Negligible association
0.10-0.20	Weak association
0.20-0.40	Moderate association
0.40-0.60	Relatively strong association
0.60-0.80	Strong association
0.80-1.00	Very strong association

3. Pearson χ^2 analysis

In Section 1, a balanced diet and aerobic exercise can reduce risk factors and the incidence of diabetes and diabetic complications, which prevents or delays the onset and progression of type 2 diabetes mellitus (T2DM) from the perspective of prediabetes research. In fact, when T2DM progresses to diabetes stage or diabetic complications stage, patients with T2DM or with diabetic complications start balanced diet and aerobic exercise. However it is medically expected that T2DM should be early intervention in low- or high-risk stage of diabetes, especially the latter stage. Taking prediabetes as the

baseline, difference knowledge of balanced diet and aerobic exercise is compared through Pearson χ^2 (given that the test level α is 0.05) forwards in low- or high-risk stage of diabetes and backwards in the diabetic stage and diabetic complication stage. Knowledge data extracted from Table 2 are analysed through formula (2) and (3) of Pearson χ^2 and formula (4) of correlation coefficient Cramer's V and Φ in the following subsections.

3.1. Forward comparison

The rationality for the forward comparison is balanced diet and aerobic exercise (intervention treatment) of T2DM as early as possible medically, since T2DM is still not eradicated at home and abroad at present. According to the natural history of T2DM, the progression stage before prediabetes includes the low- and high-risk of diabetes. Data knowledge of balanced diet and aerobic exercise at prediabetes stage and LRD stage are shown in Table 6. The minimal value of the theoretical frequency T_{ij} is 15.7647 and the total amount (425) is more than 40, thus formula (2) in Section 2 is adopted to calculate statistic χ^2=1.7664. The degree of freedom v=1, given test level α is 0.05, $\chi^2_{0.05,1}$=3.8415, $\chi^2<\chi^2_{\alpha,v}$, accept H_0.

Table 6. Knowledge of balanced diet and aerobic exercise at prediabetes stage and LRD stage.

Stage	Right	Wrong	Total	Accuracy
Prediabetes	278 (A_{11}[a])	47(A_{12})	325	85.5%
	273.7647(T_{11}[b])	51.2353(T_{12})		
LRD	80(A_{21})	20(A_{22})	100	80.0%
	84.2353(T_{21})	15.7647(T_{22})		
Total	358	67	425	84.2%

Low-Risk of Diabetes=LRD. [a] The actual frequency (A_{ij}). [b] The theoretical frequency (T_{ij}).

Data knowledge of balanced diet and aerobic exercise at prediabetes stage and HRD stage are shown in Table 7. The minimal value of the theoretical frequency T_{ij} is 12.0551 and the total amount (399) is more than 40, thus formula (2) in Section 2 is adopted to calculate statistic χ^2=4.2996. The degree of freedom v=1, given test level α is 0.05, $\chi^2_{0.05,1}$= 3.8415, $\chi^2>\chi^2_{\alpha,v}$, probability density p=0.0224<α =0.05, reject H_0, accept H_1, suggesting that the difference is statistically significant. The correlation coefficient Cramer's Φ is calculated according to formula (4) and is equal to 0.1038, and the correlation between χ^2 test results and sample size is very weak. People's knowledge of balanced diet and aerobic exercise at prediabetes stage and HRD stage is different. The knowledge of people with prediabetes is higher than that of people at high risk of diabetes. This is because general population can get the forwarded benefits of balanced diet and aerobic exercise in the prediabetes for T2DM through the Internet.

The progression to T2DM in the low-risk is quite a few, but considerable part of the high-risk of diabetes converts into prediabetes. There are already diabetic complications in the prediabetes stage; the medical equipment however cannot detect diabetic complications in this stage, i.e., false negative. This has not caused people's attention, resulting in the serious situation of diabetes in our country (ranking first in the world).

Table 7. Knowledge of balanced diet and aerobic exercise at prediabetes stage and HRD stage.

Stage	Right	Wrong	Total	Accuracy
Prediabetes	278(A_{11}[a])	47(A_{12})	325	85.5%
	272.0551(T_{11}[b])	52.9449(T_{12})		
HRD	56(A_{21})	18(A_{22})	74	75.7%
	61.9449(T_{21})	12.0551(T_{22})		
Total	334	65	399	83.7%

High-Risk of Diabetes=HRD.
[a] The actual frequency (A_{ij}).
[b] The theoretical frequency (T_{ij}).

3.2. Backward comparison

The rationality for the backward comparison is that the doctors tell patients with T2DM or with diabetic complications to practice the balanced diet and aerobic exercise (intervention treatment), but in fact patients ideologically don't pay attention to it, and the ending is disability, blindness and death. According to the natural history of T2DM, the progression stage after prediabetes includes the diabetes and diabetics complications. Data knowledge of balanced diet and aerobic exercise at prediabetes stage and diabetes stage are shown in Table 8. The minimal value of the theoretical frequency T_{ij} is 3.9886 and the total amount (352) is more than 40, thus formula (3) in Section 2 is employed to calculate statistic χ^2=0.0833. The degree of freedom v=1, given that test level α is 0.05, $\chi^2_{\alpha,v}$= 3.8415, $\chi^2<\chi^2_{\alpha,v}$, accept H_0.

Table 8. Knowledge of balanced diet and aerobic exercise at prediabetes stage and diabetes stage.

Stage	Right	Wrong	Total	Accuracy
Prediabetes	278(A_{11} [a])	47(A_{12})	325	85.5%
	276.9886(T_{11} [b])	48.0114 (T_{12})		
Diabetes	22(A_{21})	5(A_{22})	27	81.5%
	23.0114(T_{21})	3.9886(T_{22})		
Total	300	52	352	85.2%

[a] The actual frequency (A_{ij}).
[b] The theoretical frequency (T_{ij}).

Data knowledge of balanced diet and aerobic exercise at prediabetes and diabetic diabetes are shown in Table 9. The minimal value of the theoretical frequency T_{ij} is 144.3901 and the total amount (664) is more than 40, thus formula (2) in Section 2 is adopted to calculate statistic χ^2=231.5272. The degree of freedom v=1, given that test level α is 0.05, $\chi^2_{0.05,1}$= 3.8415, $\chi^2>\chi^2_{\alpha,v}$, probability density p <0.0000001<α=0.05, reject H_0, accept H_1, suggesting that the difference is statistically significant. The correlation coefficient Cramer's Φ is calculated according to formula (4) and is equal to 0.5905. Φ=0.5905 suggest that the correlation between chi-square test results and sample size is relatively strong. People's knowledge of balanced diet and aerobic exercise at prediabetes and diabetic complications is different. People's knowledge with prediabetes is statistically higher than that at diabetic complications. This is because i) T2DM is a kind of chronic disease, and patients with T2DM are no different from normal people until there are serious complications, ii) diabetics are too busy at work to have time for balanced diet and aerobic exercise, and iii) a large proportion of diabetics are elderly, and balanced diet and aerobic exercise is difficult for them. It's important to educate patients with diabetic complications about the benefits from balanced diet and aerobic exercise. The purpose of education is to expect these patients not to give up or to make time for balanced diet and aerobic exercise.

Table 9. Knowledge of balanced diet and aerobic exercise at prediabetes and diabetic complications.

Stage	Right	Wrong	Total	Accuracy
Prediabetes	278(A_{11} [a])	47(A_{12})	325	85.5%
	180.6099(T_{11} [b])	144.3901(T_{12})		
Diabetic complications	91(A_{21})	248(A_{22})	339	26.8%
	188.3901 (T_{21})	150.6099 (T_{22})		
Total	369	295	664	55.6%

[a] The actual frequency (A_{ij}). [b] The theoretical frequency (T_{ij}).

4. Conclusions

It is well-known that China has more than 116 million diabetics by 2019 and has ranked first in the world since 2010 and that one dies of diabetes every eight seconds. Type 2 diabetes mellitus (T2DM) accounts for about 95 % and is still not eradicated at home and abroad at present, thus "just control"[5]. A balanced diet and aerobic exercise (intervention treatment) can reduce risk factors and the incidence of diabetes and diabetic complications, which prevents or delays the onset and progression of T2DM.

Taking prediabetes as the baseline, difference knowledge of balanced diet and aerobic exercise is compared through Pearson χ^2 forwards in low- or high-risk stage of diabetes and backwards in the diabetic stage and diabetic complication stage. The knowledge of balanced diet and aerobic exercise at prediabetes is statistically higher than that at high-risk of diabetes. This is because general population can get the forwarded knowledge of balanced diet and aerobic exercise in the prediabetes for T2DM through the Internet. Knowledge of balanced diet and aerobic exercise at diabetic complications is significantly lower than that at prediabetes. This is because i) patients with T2DM are no different from normal people until there are serious complications, ii) diabetics are too busy at work to have time for balanced diet and aerobic exercise, and iii) a large proportion of diabetics are elderly and balanced diet and aerobic exercise is difficult for them. Therefore, doctors, nurses and researchers should use the Internet and door-to-door to educate people about the importance of balanced diet and aerobic exercise during prediabetes and diabetic complications in T2DM. The purpose of education is for patients with diabetic complications to make time for balanced diet and aerobic exercise. The more knowledge people have, they are more likely to engage in balanced diet and aerobic exercise. The associate between knowledge and action is our future work.

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