Epidemiology and Health System Journal
doi:10.34172/ehsj.26069 2024 Winter;11(1):36-42 http://ehsj.skums.ac.ir

Original Article

The Relationship Between Egg Consumption and Risk of Type 2 Diabetes in the Shahrekord Cohort Study

Atefeh Ghafari[1], Rezvan Arash[2], Tina Jafari[1,3*], Ali Ahmadi[4,5], Elahe Tavassoli[6], Ali Delgarm Shams Abadi[2]

[1]Clinical Biochemistry Research Center, Shahrekord University of Medical Sciences, Shahrekord, Iran
[2]Student Research Committee, Shahrekord University of Medical Sciences, Shahrekord, Iran
[3]Department of Biochemistry and Nutrition, Faculty of Medicine, Shahrekord University of Medical Sciences, Shahrekord, Iran
[4]Modeling in Health Research Center, Shahrekord University of Medical Sciences, Shahrekord, Iran
[5]Department of Epidemiology and Biostatistics, School of Health and Modeling in Health Research Center, Shahrekord University of Medical Sciences, Shahrekord, Iran
[6]Social Determinants of Health Research Center, Shahrekord University of Medical Sciences, Shahrekord, Iran

Abstract

Background and aims: Diabetes is a common non-communicable and metabolic disease, and its prevalence is predicted to double by 2045. It is also a significant risk factor for cardiovascular complications and mortality. The study investigated the association between egg consumption and the prevalence of type 2 diabetes (T2D) in a cohort of Iranian adults.

Methods: This study compared 261 cases of T2D with 261 controls matched for age and features and assessed their dietary intake using a food frequency questionnaire. The inclusion criterion involved the absence of concurrent chronic diseases apart from T2D.

Results: Based on the results, the participants' average age was 53.32 years, with a slightly higher proportion of females in both groups. Logistic regression analysis revealed that increased consumption of eggs is associated with a diminished risk of developing T2D ($P=0.01$).

Conclusion: The study suggests that egg consumption may have beneficial effects on glucose metabolism and insulin sensitivity, and regional and genetic differences may influence the relationship between egg consumption and T2D. It calls for further longitudinal and interventional studies to confirm the findings.

Keywords: Type 2 diabetes, Egg consumption, Cholesterol, Glycemic control, Food frequency questionnaire, Cohort study

***Corresponding Author:**
Tina Jafari,
Email: tinajafari15@yahoo.com

Received: October 9, 2023
Accepted: March 15, 2024
ePublished: March 29, 2024

Introduction

Diabetes represents a worldwide challenge in public health, characterized by persistent hyperglycemia, insulin resistance, or inadequate insulin production. Type 2 diabetes (T2D), marked by insulin resistance and a relative insufficiency of insulin, impacts approximately 90–95% of individuals diagnosed with diabetes.[1] According to the International Diabetes Federation, diabetes mellitus affected 9.3% of the global populace (approximately 463 million individuals) in 2019. It is predicted that by 2040, the number of individuals dealing with diabetes will increase to 642 million, with T2D being the most common type.[2] Diabetic patients are considered a vulnerable group due to a wide range of comorbidities. The life span of diabetic patients decreases due to the increased risk of cardiovascular disease (CVD).[3,4] T2D is highly correlated with lifestyle factors such as diet and physical activity.[5] Cholesterol, a lipid potentially related to CVD, is investigated for its potential role in causing dysfunction in pancreatic beta cells. When cholesterol accumulates in beta cells, it can interfere with their normal functioning, leading to impaired insulin production and secretion.[6]

Eggs are a notable source of dietary cholesterol and protein,[7] despite containing about 186 mg of cholesterol in a 50-g egg. They also provide numerous beneficial nutrients such as minerals, vitamins, choline, and lutein, which are associated with potential cardio-metabolic benefits.[8]

Studies regarding the relationship between egg consumption and the risk of T2D have yielded contradictory outcomes. For instance, a two-decade cohort study in the United States revealed that consuming seven eggs weekly was associated with an elevated risk of T2D.[9] In addition, a comprehensive analysis of a large group of individuals showcased a contradictory link, demonstrating a negative correlation between egg consumption and the occurrence of T2D.[10] Furthermore, a cohort study in the United Kingdom suggested a potential link between heightened egg consumption, increased blood glucose levels, and heightened susceptibility to T2D.[11] In contrast to the above-mentioned studies, several research endeavors have revealed a reverse association

between egg intake and T2D. A notable example includes a prospective cohort study in eastern Finland, which noted that the consumption of eggs was associated with a decreased incidence of T2D.[12] A review reported that components found in eggs, such as egg white hydrolysate, lutein, zeaxanthin, and angiotensin-converting enzyme inhibitory tri-peptides, could play a beneficial role in addressing T2D. This potential stems from their ability to reduce inflammation, oxidative stress, and glucose intolerance.[13] Nevertheless, it is important to note that some studies could observe a clear relationship.[14]

Regional and racial differences among the studied populations seem to play a role in these contradictions. Considering the increasing prevalence of T2D in Chaharmahal and Bakhtiari Province of Iran and the existing research gap in this area, it was decided to conduct a cohort study to determine the relationship between egg consumption and the occurrence of diabetes.

Materials and Methods

Study Population

A retrospective case-control study was performed on the Shahrekord Cohort population, Chaharmahal and Bakhtiari province, Iran. Individuals aged 35–70 who had resided in Chaharmahal and Bakhtiari province for a minimum of five years were included in this cohort project. The data from the first main stage, the data-gathering phase, were used in this study.[15] The study includes 261 cases with a confirmed diagnosis of T2D for ~5 years, according to the criteria outlined by the World Health Organization, ranging in age from 35 to 70 years.[16] Further, a total of 261 controls who were homogeneous with the case group in terms of age and features were selected, and the case-to-control ratio was 1:1. The inclusion criteria involved the absence of concurrent chronic diseases apart from T2D, the absence of cerebral complications, and the ability to provide precise responses to the survey questions. During the study, subjects who had incomplete data were excluded from the investigation.

Diabetes Assessment

T2D was determined based on the patient's fasting plasma glucose ≥ 126 mg/dL, non-fasting/random plasma glucose ≥ 200 mg/dL, hemoglobin A1C ≥ 6.5%, or use of hypoglycemic medications, depending on the availability of such data in the Shahrekord Cohort Center data bank.

Assessment of Study Variables and Egg Consumption

Demographics, individual characteristics, and physical activity data were collected, and dietary intakes were assessed at the beginning of the cohort study using a valid food frequency questionnaire. The egg consumption data were used for each group; daily egg consumption was estimated as well.[17,18] Information on dietary intakes such as proteins, carbohydrates, lipids, fibers, trans-fatty acids, saturated fatty acids, and unsaturated fatty acids was used, allowing the estimation of energy intakes, hemoglobin A1C, high-density lipoprotein (HDL), triglycerides (TG), low-density lipoprotein (LDL), and total cholesterol from the cohort data bank. The body mass index (BMI) was computed by dividing the weight in kg by the square of the height in meters. Then, the relationship between the amount of egg consumption during the day and diabetes was revealed using statistical tests. In these methods, as needed, confounding variables such as age and intake of energy and macronutrients were adjusted to remove their effect on the study of communication.

Statistical Analyses

The sample size was determined based on the previous study[19] with a 95% confidence interval, a first-type error of 0.05, and an odds ratio of 3.02, which led to 261 cases and 261 control subjects. Quantitative and qualitative data are shown as means ± standard errors, as well as numbers and percentages, respectively. Between-group analyses were conducted using the independent sample *t* test. Logistic regression was utilized to express the relationship between study variables and outcomes. All the statistical analyses were performed by SPSS software version 20.

Results

Demographic Characteristics of Participants

The participants' average age was 53.32 ± 8.15 years, with 55.9% (146 individuals) of both groups being female and 44.1% (115 individuals) being male (Table 1).

There were no significant differences in age, gender, ethnicity, or place of residence between the study groups (Table 1). However, a notable BMI disparity emerged, with diabetic individuals exhibiting a significantly higher BMI than those without diabetes (Table 1, 28.65 ± 4.35 vs. 27.35 ± 3.78, $P < 0.01$).

The Relationship Between Demographic Variables and Type 2 Diabetes

The logistic regression analysis findings indicated that higher BMIs increase the odds ratio of diabetes (Table 1, Exp. B = 1.067, $P = 0.003$).

Comparison of Consumed Eggs and Other Nutrients Among the Studied Groups

Based on the results in Table 2, egg consumption was slightly higher in non-diabetic participants ($P = 0.01$). Protein intake ($P = 0.016$), fiber intake ($P = 0.002$), and consumption of polyunsaturated fatty acids ($P = 0.016$) were higher in the group with diabetes (Table 2).

The Relationship Between Egg Consumption and Type 2 Diabetes

The logistic regression examination revealed that an increased consumption of eggs is associated with a diminished risk of developing diabetes (Table 2, Exp. B = 0.510, $P = 0.01$). As a result, a higher intake of eggs among individuals is correlated with a lower risk of developing T2D.

Table 1. Demographic Characteristics of Participants and the Relationship Between Demographic Variables and T2D

		Healthy Group	Diabetic Group	*P* Value	B	Exp. B	*P* Value
Place of residence	City	248 (95.00)	253 (96.9)	0.266	-0.505	0.603	0.270
	Village	13 (5.00)	8 (3.1)				
Nationality	Fars[a]	162 (62.1)	149 (57.1)	0.313	0.030	1.03	0.314
	Azari[b]	28 (10.7)	26 (10)				
	Lor[c]	62 (23.8)	76 (29.1)				
	Other[d]	9 (3.4)	10 (3.8)				
Age (**y**)	-	53.32 (8.159)	53.32 (8.159)	1.000	0.000	1.00	1.00
BMI (**k**g/m^2)	-	27.37 (3.997)	28.65 (4.347)	0.001	0.065	1.067	0.003
Gender	-	-	-	-	0.000	1.00	1.00

Note. T2D: Type 2 diabetes; BMI: Body mass index.
[a] It is one of the Iranian ethnicities that speaks the New Persian language and its dialects.
[b] It is one of the Iranian ethnicities that speaks the Chaharmahali Turkish language.
[c] It is one of the Iranian ethnicities that speaks the Bakhtiari Lori language.
[d] Such as Qashqai Turk, Kurd, Arab, and the like.

Table 2. Comparison of Consumed Nutrients Between the Study Groups and the Relationship Between Consumed Nutrients and T2D

		Mean ± Standard Deviation	*P* Value	B	Exp. B	*P* Value
Proteins (g/d)	Healthy group	106.68 ± 41.07	0.016	0.005	1.005	0.034
	Diabetic group	114.40 ± 41.42				
Lipids-fats (g/d)	Healthy group	93.50 ± 41.29	0.637	- 0.001	0.999	0.725
	Diabetic group	92.17 ± 44.84				
Fatty acid-total-trans (g/d)	Healthy group	0.208 ± 0.36	0.600	0.075	0.928	0.798
	Diabetic group	0.202 ± 0.21				
Fatty acid-saturated (g/d)	Healthy group	36.89 ± 18.16	0.797	- 0.004	0.996	0.402
	Diabetic group	35.54 ± 18.74				
Fatty acid- mono Unsaturated (g/d)	Healthy group	29.02 ± 15.04	0.787	- 0.005	0.995	0.423
	Diabetic group	27.94 ± 15.71				
Fatty acid- poly unsaturated (g/d)	Healthy group	14.62 ± 5.74	0.016	0.029	1.029	0.031
	Diabetic group	15.89 ± 7.57				
Acid-DHA-T (g/d)	Healthy group	0.048 ± 0.041	0.201	1.846	6.332	0.400
	Diabetic group	0.051 ± 0.039				
Acid-EPA-T (g/d)	Healthy group	0.029 ± 0.031	0.136	2.997	20.026	0.271
	Diabetic group	0.032 ± 0.033				
Carbohydrates (g/d)	Healthy group	567.56 ± 216.11	0.057	- 0.001	1.001	0.113
	Diabetic group	597.68 ± 219.47				
Fibers (g/d)	Healthy group	34.71 ± 13.56	0.002	- 0.018	1.018	0.005
	Diabetic group	38.08 ± 13.98				
Energy (kcal)	Healthy group	3505.82 ± 1124435.69	0.110	- 0.001	1.00	0.219
	Diabetic group	3641.76 ± 1289.67				
Egg consumption (number/day)	Healthy group	0.3468 ± 0.3035	0.138	- 0.673	0.510	0.01
	Diabetic group	0.2950 ± 0.4735				

Note. T2D: Type 2 diabetes.

The outcomes of the logistic regression examination indicated that increased protein consumption is associated with an increased likelihood of diabetes (Table 2, Exp. B = 1.005, $P = 0.034$). The logistic regression analysis also revealed an increased odds ratio of diabetes with increased fiber consumption (Table 2, Exp. B = 1.018, $P = 0.005$). Additionally, a rise in the risk of developing diabetes was linked to the increased consumption of polyunsaturated fatty acids (Table 2, Exp. B = 1.029, $P = 0.031$).

Comparison of Lipid Profiles in the Studied Groups

The results demonstrated that, compared to the healthy group, individuals in the diabetic group exhibited higher levels of TG ($P = 0.001$). The groups had no significant differences in terms of HDL-C, LDL-C, or cholesterol (Table 3).

Table 3. Determination and Comparison of Fat Profile and the Relationship Between Fat Profile and T2D in the Studied Groups

		Mean ± Standard Deviation	*P* Value	B	Exp. B	*P* Value
Triglyceride (mg/dL)	Healthy group	159.15 ± 83.84	0.001	0.004	1.004	0.001
	Diabetic group	198.24 ± 135.79				
Total cholesterol (mg/dL)	Healthy group	196.94 ± 43.39	0.924	- 0.003	0.997	0.152
	Diabetic group	191.41 ± 44.23				
HDL (mg/dL)	Healthy group	52.77 ± 11.74	0.958	- 0.013	0.987	0.084
	Diabetic group	51.00 ± 11.48				
LDL (mg/dL)	Healthy group	112.75 ± 37.76	0.958	- 0.008	0.992	0.002
	Diabetic group	102.83 ± 35.12				

Note. T2D: Type 2 diabetes; HDL: High-density lipoprotein; LDL: Low-density lipoprotein.

The logistic regression results revealed an elevated odds ratio for diabetes about higher TG levels (Table 3, Exp. B = 1.004, *P* = 0.001). Furthermore, the likelihood of developing diabetes was decreased associated with higher levels of LDL (Table 3, Exp. B = 0.992, *P* = 0.002).

Discussion

Eggs are affordable and low-calorie sources of many nutrients, including unsaturated fatty acids, choline, essential amino acids, iron, folate, omega-3, and vitamins.[20] Eggs also stand out among the food items with the most substantial cholesterol content, boasting a cholesterol level of 185 mg per egg. Consuming dietary cholesterol below 300 mg daily is recommended to reduce serum cholesterol levels.[21,22] In particular,[23,24] but not all[13,25,26] studies, a higher dietary cholesterol intake has been linked to a higher occurrence of T2D. In this vein, a meta-analysis revealed no correlation between the consumption of eggs and the risk of coronary artery disease or stroke.[27] However, whether there is an association between egg consumption and the risk of T2D remains uncertain. This question is of particular importance because diabetes is one of the most common non-communicable and metabolic diseases in humans, and it is predicted that its prevalence will almost double by 2045. Furthermore, diabetes mellitus constitutes a substantial risk factor for cardiovascular complications and mortality.[28]

The current study investigated the relationship between egg consumption and T2D in the Shahrekord cohort population. It compared 522 adults aged 35-70 years, including 261 with diabetes and 261 healthy individuals. The results showed that higher egg consumption decreased the chances of developing diabetes, suggesting that higher egg consumption lowers the rate of T2D. The study's large sample size and case-control nature provide statistical power to observe these relationships. Numerous studies have evaluated the relationship between egg consumption and T2D risk; however, contradictory findings have been obtained in this regard. In Finland, Virtanen et al found that high egg consumption reduced T2D risk by 38% in men aged 42-60. They also reported an inverse association between egg consumption and plasma glucose and serum CRP, suggesting an explanation for the decreased incidence of T2D.[11]

Moreover, 1165 cases of diabetes were discovered throughout the course of a 5-year follow-up in a different study involving more than 60 000 Japanese men and women. Through the application of logistic regression, it was ascertained that while the risk of developing T2D in men was unaffected by dietary cholesterol and egg consumption, these factors held a 23% probability of being associated with such a risk in women.[7] In several small randomized studies, people with metabolic syndrome who consumed three eggs daily for 12 weeks as part of a carbohydrate-restricted diet had lower plasma insulin concentrations and less insulin resistance. However, there was no difference in fasting glucose levels among overweight men.

Low plasma adiponectin has also been proposed as a risk factor for insulin resistance and T2D. Consuming eggs may enhance plasma adiponectin concentrations.[13,25] Several studies revealed that components of eggs such as egg white hydrolysate, lutein, zeaxanthin, and angiotensin-converting enzyme inhibitory tripeptides offer benefits in addressing glucose and insulin intolerance, oxidative stress, and inflammation associated with T2D. Additionally, consuming three eggs daily was linked to decreased inflammatory markers.[24,25] Another study presented contradictory findings, indicating that incorporating four eggs into the daily meals raised inflammatory markers among lean, insulin-sensitive patients; however, it did not produce the same outcome in thin or obese individuals with insulin resistance.[27]

In 2009, Djoussé et al studied 20 703 men and 36 295 women, with a 20-year follow-up period. They concluded that high egg consumption increased the risk of developing T2D in both men and women.[12] Trimethylamine-N-oxide content and egg consumption were positively correlated in the study by Tang et al.[22] Trimethylamine-N-oxide likely raises the risk of diabetes mellitus by promoting inflammation and increasing LDL oxidation.[23,24] The results of the study by Zazpe et al on 15 956 healthy Spanish participants demonstrated no link between egg consumption and diabetes development after adjusting for confounding factors (age, gender, family history, smoking and alcohol use, blood pressure, obesity, and the like). The odds ratio for diabetes in those with more than four eggs per week was 0.7. This suggests that egg consumption is not

associated with diabetes in Mediterranean populations.[29] A meta-analysis conducted by Drouin-Chartier et al[30] revealed that daily egg consumption was associated with a 14% higher risk of developing T2D. However, an updated meta-analysis of 16 studies found no significant relationship between egg consumption and T2D risk. The study also reported a significant difference based on geographical region, with one egg per day associated with an increased risk of T2D in US studies but no association detected in Europeans or Asians.[9] Moreover, Djoussé et al reported an increased risk of T2D in US individuals with three or more eggs per week; however, this correlation was not observed in studies conducted outside of the United States.[9]

The reality that eggs are typically consumed as a component of a mixed dish rather than being consumed alone can be one explanation for these contrary findings. For instance, eggs are frequently consumed with refined cereals, sweet drinks, and processed red meat, which has been linked to an increased risk of T2D.[12,26] Additionally, people who consumed more eggs were more likely to smoke and engage in less physical activity during their free time, according to some studies that linked a higher egg intake to a reduced risk of T2D.[12,13] However, epidemiological evidence shows that a healthy diet rich in vegetables, fruits, and grains significantly reduces the risk of developing diabetes. Olive oil, fruits, vegetables, nuts, and whole grains may protect against insulin resistance and metabolic syndrome. Despite high egg consumption, a moderate diet may protect individuals against diabetes.[27] Demographic differences, dietary habits, egg consumption, and genetic factors influence the relationship between egg consumption and diabetes in different regions. Individual responses to dietary cholesterol vary due to genetic and non-genetic factors. Reducing cholesterol intake by 100 mg daily only reduces total plasma cholesterol in 30% of people.[28,31] In the present study, two diabetic groups were examined regarding consuming different food items. After adjusting for confounding factors, it was observed that egg consumption is associated with a decrease in the risk of diabetes; however, the relationship between the amount and frequency of egg consumption and the chance of developing diabetes was not determined in this study.

The findings demonstrated that higher protein intake (Exp B = 1.005, $P = 0.034$) and increased consumption of polyunsaturated fatty acids (Exp B = 1.029, $P = 0.031$) correlate with an elevated probability of diabetes. Conversely, diabetes probability decreases with reduced fiber consumption (Exp B = 1.018, $P = 0.005$). The findings of a study confirmed that increasing fiber intake by 1 SD reduced diabetes risk by 39%, while increasing protein intake increased it by 38%.[28] Based on the results of a study on 200 000 people, participants in the top 25% for energy obtained from total protein and animal protein exhibited a 7% and 13% higher likelihood of developing T2D, respectively. However, receiving a percentage of energy from plant-based protein reduced the average risk of T2D by 41%, and replacing 5% of vegetable protein with animal protein reduced the risk by 23%.[31]

Studies on the relationship between unsaturated fatty acids and diabetes risk have shown contradictory results. The findings of a 14-year follow-up study revealed that trans fatty acids are associated with an increased risk of T2D in women.[32] In contrast, polyunsaturated fatty acids are linked with a decreased risk.[33] Zheng et al found an inverse relationship between fish consumption and marine n-3 fatty acids and T2D in Asian populations.[33] Muley et al concluded that marine n-3 fatty acids are related to a reduced risk of T2D in both Australian and Asian cohorts.[34] However, Zhou et al reported that consuming fish four times a month and 0.1 g of marine n-3 fatty acids daily increased the risk of T2D.[35] A prospective study from the Australian Longitudinal Study of Women's Health demonstrated that total n-3 fatty acids are associated with a 55% increased risk of T2D in Australian women.[36]

Based on the results of the present study, a decrease in diabetes risk was associated with lower BMI and higher LDL levels. Conversely, the risk tends to rise with elevated TG levels. In line with our findings, studies showed that BMI is the strongest predictor of T2D. At certain levels, it is significantly related to TG levels. However, higher LDLC levels are associated with a higher risk of T2D, regardless of age, gender, fasting plasma glucose, waist circumference, or blood pressure.[5,37,38] LDL-C levels do not necessarily increase in T2D; however, the increase in small and dense particles (LDL) is twice as high in diabetic men with normal lipid levels.[39] Exposure to LDL-C-lowering genetic variants is related to a higher risk of T2D, providing interdisciplinary insight into the potential adverse effects of LDL-C-lowering therapy.[40] Longitudinal cohort studies are needed to evaluate the relationship between deficient LDL-C levels and the risk of developing T2 diabetes.[41]

Conclusion

In the current study on adults in the Shahrekord cohort study, there were no significant differences between the two study groups regarding age, gender, ethnicity, or place of residence. Average BMI and blood TG were significantly higher in diabetic subjects than subjects without diabetes. Diabetic patients also significantly consumed more protein, fiber, and polyunsaturated fatty acids than other groups. The logistic regression results revealed that the probability of developing diabetes increases with more protein and polyunsaturated fatty acids while decreasing with higher fiber consumption and eggs. The results of the logistic regression test also showed that the probability of diabetes decreases with lower BMI and higher LDL. At the same time, it rises with elevated TG levels. Overall, our findings demonstrated that consumption of eggs may decrease the progression of diabetes. However, the retrospective nature of the study does not permit the drawing of a precise conclusion, and this is one of the limitations of the study. Lack of data on the type of egg the

population consumed and incomplete data on variables such as HbA1c also cause some limitations in the analyses and conclusions. Accordingly, it is recommended that researchers perform more precise and prospective studies on the other parts of the Persian Cohort in this field.

Acknowledgments

This article was derived from a research project approved by the Research and Technology Deputy of Shahrekord University of Medical Sciences (Approval No. IR.SKUMS.REC.1400.135). Hereby, the researchers gratefully thank the patients who participated in this study.

Authors' Contribution

Conceptualization: Tina Jafari.
Data curation: Tina Jafari, Atefeh Ghafari.
Formal analysis: Ali Ahmadi, Elahe Tavassoli.
Funding acquisition: Ali Ahmadi, Tina Jafari.
Investigation: Ali Ahmadi, Tina Jafari, Atefeh Ghafari.
Methodology: Ali Ahmadi, Tina Jafari, Elahe Tavassoli.
Project administration: Tina Jafari.
Resources: Ali Ahmadi, Tina Jafari.
Software: Tina Jafari, Elahe Tavassoli.
Supervision: Tina Jafari.
Validation: Tina Jafari, Ali Ahmadi.
Visualization: Rezvan Arash, Ali Delgarm Shams Abadi, Tina Jafari.
Writing–original draft: Rezvan Arash, Ali Delgarm Shams Abadi, Tina Jafari.
Writing–review & editing: Rezvan Arash, Ali Delgarm Shams Abadi, Tina Jafari.

Competing Interests

The authors declare that there is no conflict of interests.

Ethical Approval

Ethical considerations in this study included obtaining permission from the Ethics Committee of Shahrekord University of Medical Sciences (Ethical Approval No. IR.SKUMS.REC.1400.135) and obtaining written consent to participate in the study from the participants.

Funding

The study received financial support from Shahrekord University of Medical Sciences.

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