湖南大学学报（自然科学版）
Journal of Hunan University (Natural Sciences)

第 50 卷 第 2 期
2023 年 2 月

Available online at http://jonuns.com/index.php/journal/index

Vol. 50 No. 2
February 2023

Open Access Article

https://doi.org/10.55463/issn.1674-2974.50.2.27

Study Protocol: Comparison of Magnesium versus Potassium and Their Combined Effect on Insomnia, Sleep Hormones, Insulin Resistance, and Quality of Life among Patients with Diabetes Mellitus

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Received: December 11, 2022 ▪ Review: January 16, 2023 ▪ Accepted: February 15, 2023 ▪ Published: February 27, 2023

Abstract: Insomnia has been associated with changes in metabolism causing irregular insulin secretion, insulin insensitivity, and poor glucose metabolism, increasing the risk of diabetes mellitus. Magnesium and potassium are electrolytes that play a key role in the regulation of sleep hormones and other factors that contribute to insomnia and diabetes collectively. The study contributes to the literature, as the scientific novelty of the article is targeting the insomnia and diabetes together with potassium and magnesium with a considerable sample size. The Objective of the study was the comparison between magnesium and potassium and determining their combined effect on insomnia, insulin resistance, and quality of life among patients with diabetes mellitus. Methods: In the future, a study with single blind randomized controlled trial will occur. The clinical trial registration number is NCT04642313. The study will occur at the Diabetes Center of Akhuwat Health Services, Lahore, within 18 months. Sample size will be of 320 individuals having diabetes mellitus and insomnia from both genders aged between 19 to 65 years. The control group will be given a placebo. The experimental group will receive the intervention in the form of Magnesium (Mg), Potassium (K), and Mg+K tablets. Outcome measures will include dependent and independent variables along with BMI, blood glucose measurements, and measurement of sleep parameters. Quantitative data will be presented as mean and standard deviation. After the data collection, SPSS Version 25.0 will be used for the analysis. For comparison between treatments ANOVA test will be applied while the chi-square test will be used to analyze categorical data. It is expected that the results will provide useful insights into the effectiveness of clinical interventions on the quality of life among patients with diabetes mellitus.

Keywords: insomnia, diabetes, potassium, magnesium, sleep hormones.

研究方案：镁与钾的比较及其对糖尿病患者失眠、睡眠激素、胰岛素抵抗和生活质量的综合影响

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摘要：失眠与新陈代谢的变化有关，导致胰岛素分泌不规律、胰岛素不敏感和葡萄糖代谢不良，从而增加患糖尿病的风险。镁和钾是电解质，在调节睡眠激素和其他共同导致失眠和糖尿病的因素中起着关键作用。该研究对文献有贡献，因为该文章的科学新颖性是针对失眠和糖尿病以及具有相当大样本量的钾和镁。该研究的目的是比较镁和钾，并确定它们对糖尿病患者失眠、胰岛素抵抗和生活质量的综合影响。方法：未来将进行单盲随机对照试验研究。临床试验注册号为 NCT04642313。该研究将在 18 个月内在拉合尔阿库瓦特健康服务糖尿病中心进行。样本量为 320 名 19 至 65 岁之间患有糖尿病和失眠症的男女。对照组将给予安慰剂。实验组将接受镁(镁)、钾(钾)和镁+钾片剂形式的干预。结果测量将包括因变量和自变量以及体重指数、血糖测量和睡眠参数测量。定量数据将以平均值和标准差表示。数据收集完成后，将使用 SPSS 25.0 进行分析。对于处理之间的比较，将应用方差分析检验，而卡方检验将用于分析分类数据。预计该结果将为临床干预对糖尿病患者生活质量的有效性提供有用的见解。

关键词：失眠，糖尿病，钾，镁，睡眠激素。

1. Introduction

Sleep is the essential component to maintain the good health of an individual [1]. Insomnia is defined as a condition that affects an individual by inability to obtain sufficient quality sleep or problem in maintaining sleep that is important for healthy functioning, performance, and wellbeing [2]. Insomnia can exist in healthy individuals or co-morbidly with other diseases [3]. It is described by trouble starting or potentially looking after rest, and is related to critical pain or daytime impedances, regardless of sufficient rest opportunity. Clinical analysis depends on the nearness of these abstract symptoms amid somewhere around three evenings for every week, for no less than three months [4]. Insomnia can be either acute or chronic or can be primary or secondary. Acute insomnia lasts up to three weeks and mostly has unidentifiable cause, while chronic insomnia is an abnormal state of increased responsiveness to stimuli called hyperarousal, and it is considered to be associated with a rise in sympathetic nervous system (SNS) activity and hormones involved in wakefulness and sleeplessness, for example cortisol. According to proofs, insomniac patients have high secretion of adrenocorticotropic hormone and cortisol, especially patients with objective short sleep duration. This shows elevated activity of the HPA axis [5]. Latest research indicated that the intolerance of glucose in the body, resistance to insulin hormone, decreased acute response of insulin to glucose, and increased chances of having type 2 diabetes are reasons for reduced or interrupted sleep [20]. In addition to this, cardiovascular diseases, poor life quality, and economic stress are also the contributors. As sleep regulates the metabolism of glucose and a stable internal environment and affects the quality of life, it is necessary to identify sleep issues for the management of type 2 diabetes [6]. DM leads to a wide range of changes in the neural structure of the brain, neurotransmitter levels, electrophysiology, and blood circulation [7, 21]. Several electrolytes and minerals influence the sleep cycle. Magnesium is important in the regulation of central nervous system excitability, through ion channel conductivity [8]. It acts as an N-methyl-D-aspartate antagonist and gamma-amino butyric acid agonist, thereby promoting sleep [9]. Magnesium supplementation improves sleep efficiency, sleep time and sleep onset latency, early morning awakening, and insomnia objective measures such as the concentration of serum rennin, melatonin, and serum cortisol, in older adults [10]. Potassium depletion causes glucose intolerance, which is associated with impaired insulin secretion. On the other hand, potassium infusion and hyperkalemia increase insulin secretion and decrease plasma glucose levels, possibly through modulation of the membrane potential of pancreatic β-cells. On the cellular level, potassium is central to blood glucose control by being involved in the secretion of pancreatic insulin [11].

Insomnia is increasing alarmingly among the population; moreover, micronutrients are usually being ignored in the diet due to inappropriate dietary patterns or lack of awareness. The study is aimed to identify the effect of magnesium and potassium supplementation on insomnia patients having diabetes. This study hypothesized that magnesium and potassium supplementation affect the severity and duration of insomnia. This study will help determine the link between insomnia and micronutrients so that the burden of the disease in society could be reduced.

2. Methods

This single-blind randomized control trial will be conducted at the Diabetes Center of Akhuwat Health Services, Lahore, within 18 months. Sample size was calculated using the WHO formula for sample size calculation. A total of 320 sample size was calculated after adjusting 20% drop-out rate with each treatment group having 80 subjects, as shown in Fig. 1. Non-probability purposive sampling will be used to include patients with diabetes mellitus with insomnia aged between 19 and 65, of both genders. These patients might or might not be using antidiabetic drugs and are with or without hypomagnesaemia and hypokalemia. Patients of diabetes mellitus with insomnia having psychiatry reasons, any hormonal treatment, CVD/other metabolic co-morbidities, history of acute liver injury (e.g., hepatitis, ascites) or severe cirrhosis, renal diseases (renal stones, renal failure, dialysis), diabetic nephropathy, pregnancy, breast-feeding, drug-induced insomnia, sleep disorders, sleep-related movement disorders (restless leg syndrome), sleep-related respiratory disorders (sleep apnea), alcohol consumption, cardiac respiratory disorders, painful condition (apathy), history of chronic liver disease, and are a participant in a study of an investigational medication or nutritional supplements/medication within the past 90 days are excluded from the study. Patients who will fulfill the inclusion and exclusion criteria and give consent will be enrolled in the study. Patients diagnosed with diabetes mellitus (I, II) with or without antidiabetic drugs, visiting diabetic centres (of selected study settings) will be interviewed for insomnia; using the Insomnia Severity Index (ISI). Prior clinical history of the patients, fasting, random blood glucose level, HbA1c, and insulin values will be used as enrollment baseline for the study. ISI will be used to interview the patient for meeting the study criteria. If the patients are categorized according to the insomnia severity index, they will be enrolled for the study. Patients with co-morbidities mentioned above will not be enrolled. Unwilling patients will not be selected. Demographic Performa, wellbeing scoring, 24-h dietary recall, WHOQOL-BREF will be used to collect data from patients. Patients' random/fasting blood glucose level will be measured using the glucometer strip method. The patient will then be referred to the physician for the allocation of treatment. The doctor will randomly allocate any of the treatment groups T1, T2, T3, and T4 to the patients. Blinding will be done by the physician. The physician will administer tablets of Placebo, Magnesium (Mg), Potassium (K), and Mg+K to the allocated groups. For Placebo tablets, starch (250 mg in each tablet) will be used. For Mg tablets, magnesium gluconate salt will be used (each containing 414 mg magnesium gluconate as 250 mg elemental Mg). For K tablets, Potassium chloride salt will be used. The physician will ensure the patient to give blood sample (in fasting) next morning or on the spot (if in fasting condition) to the pathology of visiting the Diabetes Centre of Akhuwat Health Services. A qualified phlebotomist will take the blood sample, store it, and tests will be performed for the following parameters:

- Serum Mg
- Serum K
- Serum Melatonin
- Serum Cortisol
- Serum Insulin

On-call follow-up will be taken after 7-10 days to determine the follow-up/dropout rate or any side effect. Patients will be advised for monthly follow-up, so that treatments/supplement could be provided again for the next month. After 8 weeks physician will again ensure the patient to give blood sample (in fasting) next morning or on the spot (if in fasting condition).

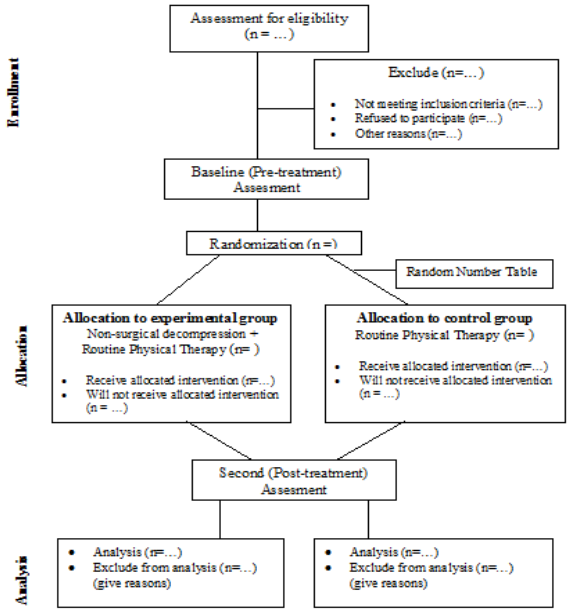

Fig. 1 CONSORT flow diagram representing the RCT details. This diagram will help interpret the results of this randomized control trial in a more precise way

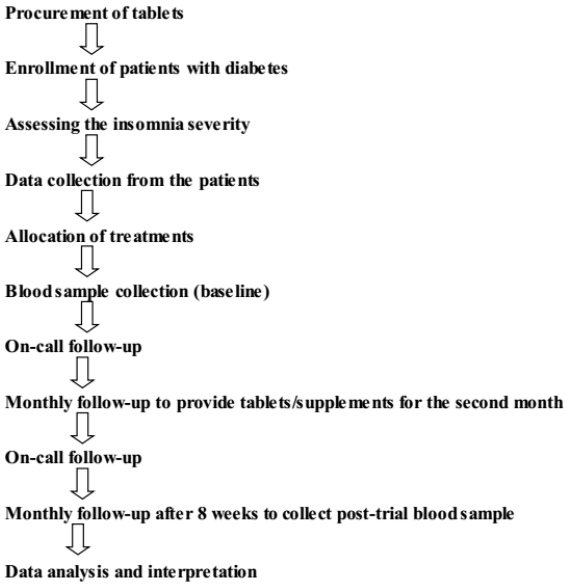

Fig. 2 Schematic representation of the study

2.1. Control Group

The control group will be given a placebo.

2.2. Experimental/Treatment Group

The experimental group will receive the intervention in the form of Magnesium (Mg), Potassium (K), and Mg+K tablets.

2.3. Outcome Measures

2.3.1. Independent Variables

1. Magnesium and/or potassium supplement (250 mg) vs. Placebo tablets once daily
2. Age
3. Gender
4. Feeding (supplementation) interval

2.3.2. Dependent Variables

1. Fasting blood sugar
2. Fasting insulin
3. BMI
4. Serum electrolytes (Mg, K)
5. Homa-IR
6. Sleep hormones: melatonin and cortisol
7. Insomnia Severity Index
8. Total sleep time
9. Early morning awakening
10. Sleep efficiency

2.4. Data Analysis

Data will be entered and analyzed using SPSS version 25.0. Numeric data such as age and blood glucose level will be presented in the form of Mean± SD while categorical data like gender, diabetes status, insomnia categories will be presented in the form of percent frequencies. Data such as random serum glucose levels and BMI will be subjected to Analysis of Variance (ANOVA) using factorial arrangement (Factors: Age (3) X Supplements (2) X Intervals (2)). Means will be separated using the Tukey test. Categorical data will be analysed using chi-square test, and p-value ≤ 0.05 will be considered as significant.

2.5. Ethical Considerations

The study has been approved from the Institutional Review Board (IRB) of The University of Lahore, Lahore, Pakistan with reference number: IRB-UOL-FAHS/760/2020. The rules and regulations set by the ethical committee of the University of Lahore will be followed while conducting the research, and the rights of the research participants will be respected.

2.6. Statement of Confidentiality

The medical or personal information obtained from the participants will be kept confidential, and its disclosure will be prohibited.

3. Discussion

Researchers have associated disturbed sleep patterns and low or restricted sleep duration with the onset of metabolic complications such as slowing down of glucose metabolism and diabetes. Patients with diabetes tend to have disrupted circadian rhythms along with having a lack of sleep. A study by Buxton in 2012 examined the effect of restricted sleep on the glucose metabolism in healthy people for 5 weeks. A meta-analysis was also performed in 2015 by Shan et al. on a similar topic. Both studies showed a decrease in the resting metabolism of glucose and an increase in insulin resistance along with disruption of regular circadian rhythms, increasing overall blood glucose levels and the risk of diabetes [12, 13].

As the daily sleep debt of a person increases, it elevates the risk of metabolic abnormalities. A common commotion in metabolic activity resulting in insulin resistance and decreased pancreatic insulin secretion is seen in patients recently diagnosed with type 2 diabetes, having a daily sleep debt. With the passage of time, the risk of progressive severity in diabetic conditions in conjunction with obesity increased up to 17%, according to research conducted by Arora et al. in 2016 [14].

Out of the naturally occurring minerals, magnesium and potassium have a profound effect on insomnia. Magnesium has been associated with the onset and improvement of sleep, actively waking up in the morning, and normalization of factors that contribute to insomnia. Low levels of magnesium or hypomagnesaemia are presented in patients with diabetes. In the body, hypomagnesaemia is linked with restricted sleep, changes in the circadian rhythms, and lack of sleep or insomnia, as depicted by studies performed by De Baaji in 2015 and Abbasi et al. in 2012 [15, 16]. In an attempt to treat insomnia in patients with diabetes, magnesium supplementation has shown considerable positive effects. As magnesium plays a role in neural excitability and hyperarousal, its supplementation together with the Vitamin B complex positively controls and regulates normal neural pathways in diabetic and hypomagnesaemia patients [17].

Diabetes results in irregularities in serum electrolyte concentration. Parallel to magnesium potassium also plays a significant role in the regulation of sleep duration and its quality, but its mechanism is ambiguous and requires extensive research. However, hyper- and hypokalemia increase mortality in patients with type 2 diabetes. People having diabetes and hypokalemia may benefit from potassium supplementation; however, patients with diabetes presented with hyperkalemia need to lower their potassium levels for exhibiting normal sleep as per studies conducted by researchers in 2017 [18, 19]. Evidence on the potential association between potassium and insomnia is still missing, and more

research-based data must authenticate their relationship.

4. Conclusion and Recommendations

Magnesium and potassium supplementation may improve insomnia, sleep hormones, insulin resistance, and quality of life in patients with diabetes mellitus. The combination of magnesium and potassium supplementation may have a greater effect on improving these outcomes compared with either mineral alone. According to the previous literature, magnesium and potassium supplementation had been examined on diabetes and insomnia separately, but no or limited research data is available on their combination or separate effect on diabetic people with insomnis. The study is unique in a way that it is targeting insomnia and diabetes combined, along with both minerals. Based on these findings, magnesium and potassium supplementation could be considered an adjunctive therapy for managing sleep disturbance and improving the quality of life in patients with diabetes mellitus. It will add new knowledge in the field by answering the questions not addressed in previous research. Novel aspects of this research are the insights into the role of essential micronutrients potassium and magnesium in insomnia in patients with diabetes. Healthcare providers may consider recommending magnesium and potassium supplementation as an adjunctive therapy for managing sleep disturbance and improving the quality of life in patients with diabetes mellitus. It could lead to an increased use of magnesium and potassium supplementation as an adjunctive therapy in the management of sleep disturbance and quality of life in patients with diabetes mellitus.

4.1. Limitations

The current study has been planned to conduct to on a specific population area, with the same ethnicity group, which may not lead to the diversity of study findings.

References

[1] CHAPUT J. P. and DUTIL C. Lack of sleep as a contributor to obesity in adolescents: impacts on eating and activity behaviors. *International Journal of Behavioral Nutrition and Physical Activity*, 2016, 13: 1-9. https://doi.org/10.1186/s12966-016-0428-0

[2] BOS S. C. and MACEDO A. F. Literature review on Insomnia (2010–2016). *Biological Rhythm Research*, 2019, 50(1): 94-163. https://doi.org/10.1080/09291016.2017.1413766

[3] MORIN C. M. and BENCA R. Chronic insomnia. *The Lancet*, 2012, 379(9821): 1129-1141. https://doi.org/10.1016/S0140-6736(11)60750-2

[4] ARAÚJO T., JARRIN D. C., LEANZA Y., VALLIÈRES A., and MORIN C. M. Qualitative studies of insomnia: Current state of knowledge in the field. *Sleep Medicine Reviews*, 2017, 31: 58-69. https://doi.org/10.1016/j.smrv.2016.01.003

[5] JAVAHERI S. and REDLINE S. Insomnia and risk of cardiovascular disease. *Chest*, 2017, 152(2): 435-444. https://doi.org/10.1016/j.chest.2017.01.026

[6] CHO E. H., LEE H., RYU O. H., CHOI M. G., and KIM, S. W. Sleep disturbances and glucoregulation in patients with type 2 diabetes. *Journal of Korean Medical Science*, 2014, 29(2): 243-247. https://doi.org/10.3346/jkms.2014.29.2.243

[7] ZHANG S., LI H., ZHANG L., LI J., WANG R., and WANG M. Effects of troxerutin on cognitive deficits and glutamate cysteine ligase subunits in the hippocampus of streptozotocin-induced type 1 diabetes mellitus rats. *Brain Research*, 2017, 1657: 355-360. https://doi.org/10.1016/j.brainres.2016.12.009

[8] CHOLLET D., FRANKEN P., RAFFIN Y., MALAFOSSE A., WIDMER J., and TAFTI M. Blood and brain magnesium in inbred mice and their correlation with sleep quality. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, 2000, 279(6): R2173-R2178. https://doi.org/10.1152/ajpregu.2000.279.6.R2173

[9] TATSUKI F., SUNAGAWA G. A., SHI S., SUSAKI E. A., YUKINAGA H., PERRIN D., SUMIYAMA K., UKAI-TADENUMA M., FUJISHIMA H., OHNO R. I., and TONE D. Involvement of Ca2+-dependent hyperpolarization in sleep duration in mammals. *Neuron*, 2016, 90(1): 70-85. https://doi.org/10.1016/j.neuron.2016.02.032

[10] ABBASI B., KIMIAGAR M., SADEGHNIIAT K., SHIRAZI M. M., HEDAYATI M., and RASHIDKHANI B. The effect of magnesium supplementation on primary insomnia in elderly: a double blind placebo-controlled clinical trial. *Journal of Research in Medical Sciences*, 2012, 17(12): 1161-1169. http://jrms.mui.ac.ir/index.php/jrms/article/view/8839

[11] SCHMID D., STOLZLECHNER M., SORGNER A., BENTELE C., ASSINGER A., CHIBA P., and MOESLINGER T. An abundant, truncated human sulfonylurea receptor 1 splice variant has prodiabetic properties and impairs sulfonylurea action. *Cellular and Molecular Life Sciences*, 2012, 69: 129-148. https://doi.org/10.1007/s00018-011-0739-x

[12] BUXTON O. M., CAIN S. W., O'CONNOR S. P., PORTER J. H., DUFFY J. F., WANG W., CZEISLER C. A., and SHEA S. A. Adverse metabolic consequences in humans of prolonged sleep restriction combined with circadian disruption. *Science Translational Medicine*, 2012, 4(129): 129ra43. https://doi.org/10.1126/scitranslmed.3003200

[13] SHAN Z., MA H., XIE M., YAN P., GUO Y., BAO W., RONG Y., JACKSON C. L., HU F. B., and LIU L. Sleep duration and risk of type 2 diabetes: a meta-analysis of prospective studies. *Diabetes Care*, 2015, 38(3): 529-537. https://doi.org/10.2337/dc14-2073

[14] ARORA T., CHEN M. Z., COOPER A. R., ANDREWS R. C., and TAHERI S. The impact of sleep debt on excess adiposity and insulin sensitivity in patients with early type 2 diabetes mellitus. *Journal of Clinical Sleep Medicine*, 2016, 12(5): 673-680. https://doi.org/10.5664/jcsm.5792

[15] NIELSEN F. H., JOHNSON L. K., and ZENG H. Magnesium supplementation improves indicators of low magnesium status and inflammatory stress in adults older than 51 years with poor quality sleep. *Magnesium Research*, 2010, 23(4): 158-168.

https://doi.org/10.1684/mrh.2010.0220
[16] DE BAAIJ J. H., HOENDEROP J. G., and BINDELS R. J. Magnesium in man: implications for health and disease. *Physiological Reviews*, 2015, 95: 1-46. https://doi.org/10.1152/physrev.00012.2014
[17] FENG J., WANG H., JING Z., WANG Y., CHENG Y., WANG W., and SUN W. Role of magnesium in type 2 diabetes mellitus. *Biological Trace Element Research*, 2020, 196: 74-85. https://doi.org/10.1007/s12011-019-01922-0
[18] COLLINS A. J., PITT B., REAVEN N., FUNK S., MCGAUGHEY K., WILSON D., and BUSHINSKY D. A. Association of serum potassium with all-cause mortality in patients with and without heart failure, chronic kidney disease, and/or diabetes. *American Journal of Nephrology*, 2017, 46(3): 213-221. https://doi.org/10.1159/000479802
[19] NILSSON E., GASPARINI A., ÄRNLÖV J., XU H., HENRIKSSON K. M., CORESH J., GRAMS M. E., and CARRERO J. J. Incidence and determinants of hyperkalemia and hypokalemia in a large healthcare system. *International Journal of Cardiology*, 2017, 245: 277-284. https://doi.org/10.1016/j.ijcard.2017.07.035
[20] BAAREH L. A., ALSAYED A. R., AYASRAH S., and BASHETI I. A. Effects of a Medication Management Review Service on Patients Diagnosed with Type II Diabetes: A Randomized Controlled Trial. *Journal of Southwest Jiaotong University*, 2022, 57(6): 840-859. https://doi.org/10.35741/issn.0258-2724.57.6.73
[21] HAKAEW U., LAOHASIRIWONG W., and SAKPHISUTTHIKUL C. Obesity, Depression, Demographics Factors and Type 2 Diabetes Mellitus among Middle-Aged Population in Thailand. *Journal of Southwest Jiaotong University*, 2021, 56(6): 580-587. https://doi.org/10.35741/issn.0258-2724.56.6.50

参考文:

[1] CHAPUT J. P. 和 DUTIL C. 睡眠不足是青少年肥胖的一个因素：对饮食和活动行为的影响。国际行为营养与身体活动杂志，2016 年，13：1-9。https://doi.org/10.1186/s12966-016-0428-0
[2] BOS S. C. 和 MACEDO A. F. 失眠文献综述（2010-2016）。生物节律研究，2019, 50(1): 94-163. https://doi.org/10.1080/09291016.2017.1413766
[3] MORIN C. M. 和 BENCA R. 慢性失眠。柳叶刀，2012 年，379(9821)：1129-1141。https://doi.org/10.1016/S0140-6736(11)60750-2
[4] ARAÚJO T.、JARRIN D. C.、LEANZA Y.、VALLIÈRES A. 和 MORIN C. M. 失眠的定性研究：该领域的知识现状。睡眠医学评论，2017 年，31：58-69。https://doi.org/10.1016/j.smrv.2016.01.003
[5] JAVAHERI S. 和 REDLINE S. 失眠和心血管疾病的风险。胸部，2017, 152(2): 435-444. https://doi.org/10.1016/j.chest.2017.01.026
[6] CHO E. H.、LEE H.、RYU O. H.、CHOI M. G. 和 KIM, S. W. 2 型糖尿病患者的睡眠障碍和血糖调节。大韩医学杂志，2014, 29(2): 243-247. https://doi.org/10.3346/jkms.2014.29.2.243
[7] ZHANG S., LI H., ZHANG L., LI J., WANG R., 和 WANG M. 曲克芦丁对链脲佐菌素诱导的 1 型糖尿病大鼠认知缺陷和海马谷氨酸半胱氨酸连接酶亚基的影响. 大脑研究，2017 年，1657：355-360。https://doi.org/10.1016/j.brainres.2016.12.009
[8] CHOLLET D.、FRANKEN P.、RAFFIN Y.、MALAFOSSE A.、WIDMER J. 和 TAFTI M. 近交系小鼠的血液和脑镁及其与睡眠质量的相关性。美国生理学杂志-调节、综合和比较生理学，2000 年，279(6)：R2173-R2178。https://doi.org/10.1152/ajpregu.2000.279.6.R2173
[9] TATSUKI F.、SUNAGAWA G.A.、SHI S.、SUSAKI E.A.、YUKINAGA H.、PERRIN D.、SUMIYAMA K.、UKAI-TADENUMA M.、FUJISHIMA H.、OHNO R.I. 和 TONE D. 参与 Ca2+-哺乳动物睡眠时间的依赖性超极化。神经元，2016, 90(1): 70-85. https://doi.org/10.1016/j.neuron.2016.02.032
[10] ABBASI B.、KIMIAGAR M.、SADEGHNIIAT K.、SHIRAZI M.M.、HEDAYATI M. 和 RASHIDKHANI B. 补充镁对老年人原发性失眠的影响：双盲安慰剂对照临床试验。医学科学研究杂志，2012, 17(12): 1161-1169. http://jrms.mui.ac.ir/index.php/jrms/article/view/8839
[11] SCHMID D.、STOLZLECHNER M.、SORGNER A.、BENTELE C.、ASSINGER A.、CHIBA P. 和 MOESLINGER T. 一种丰富的、截短的人磺酰脲受体 1 剪接变体具有促糖尿病特性并损害磺酰脲作用。细胞与分子生命科学，2012, 69: 129-148. https://doi.org/10.1007/s00018-011-0739-x
[12] BUXTON O.M.、CAIN S.W.、O'CONNOR S.P.、PORTER J.H.、DUFFY J.F.、WANG W.、CZEISLER C.A. 和 SHEA S.A. 长期睡眠限制与昼夜节律紊乱对人类的不良代谢后果。科学转化医学，2012, 4(129): 129ra43. https://doi.org/10.1126/scitranslmed.3003200
[13] SHAN Z., MA H., XIE M., YAN P., GUO Y., BAO W., RONG Y., JACKSON C. L., HU F. B., 和 LIU L. 睡眠时间和 2 型糖尿病的风险：前瞻性研究的荟萃分析。糖尿病护理，2015 年，38(3)：529-537。https://doi.org/10.2337/dc14-2073
[14] ARORA T.、CHEN M. Z.、COOPER A.R.、ANDREWS R.C. 和 TAHERI S. 睡眠不足对早期 2 型糖尿病患者过度肥胖和胰岛素敏感性的影响。临床睡眠医学杂志，2016, 12(5): 673-680. https://doi.org/10.5664/jcsm.5792
[15] NIELSEN F. H.、JOHNSON L. K. 和 ZENG H. 补充镁可改善 51 岁以上睡眠质量差的成年人的低镁状态和炎

症应激指标。镁研究，2010，23(4)：158-168. https://doi.org/10.1684/mrh.2010.0220
[16] DE BAAIJ J. H.、HOENDEROP J. G. 和 BINDELS R. J. 人体中的镁：对健康和疾病的影响。生理评论，2015 年，95：1-46。https://doi.org/10.1152/physrev.00012.2014
[17] FENG J., WANG H., JING Z., WANG Y., CHENG Y., WANG W., 和 SUN W. 镁在 2 型糖尿病中的作用。生物微量元素研究，2020，196：74-85. https://doi.org/10.1007/s12011-019-01922-0
[18] COLLINS A.J.、PITT B.、REAVEN N.、FUNK S.、MCGAUGHEY K.、WILSON D. 和 BUSHINSKY D.A. 血清钾与患有和不患有心力衰竭、慢性肾病的患者的全因死亡率的关联，和/或糖尿病。美国肾脏病学杂志，2017 年，46(3)：213-221。https://doi.org/10.1159/000479802
[19] NILSSON E.、GASPARINI A.、ÄRNLÖV J.、XU H.、HENRIKSSON K.M.、CORESH J.、GRAMS M.E. 和 CARRERO J.J. 大型医疗保健系统中高钾血症和低钾血症的发病率和决定因素。国际心脏病学杂志，2017 年，245：277-284。https://doi.org/10.1016/j.ijcard.2017.07.035
[20] BAAREH L.A.、ALSAYED A.R.、AYASRAH S. 和 BASHETI I.A. 药物管理审查服务对诊断为 II 型糖尿病患者的影响：一项随机对照试验。西南交通大学学报，2022，57(6)：840-859. https://doi.org/10.35741/issn.0258-2724.57.6.73
[21] HAKAEW U.、LAOHASIRIWONG W. 和 SAKPHISUTTHIKUL C. 泰国中年人口的肥胖、抑郁、人口统计学因素和 2 型糖尿病。西南交通大学学报，2021，56(6)：580-587. https://doi.org/10.35741/issn.0258-2724.56.6.50