Journal of Yoga & Physical Therapy
ISSN: 2157-7595

Wilson et al., J Yoga Phys Ther 2017, 7:2
DOI: 10.4172/2157-7595.1000270

Review Article Open Access

Review: Can Yoga Breathing Exercises Improve Glycemic Response and Insulin Sensitivity?

Ted Wilson[1]*, Kevin L Kelly[2] and Sarah E Baker[3]

[1]*Department of Biology, Winona State University, Winona, Minnesota, USA*
[2]*Department of Cardiovascular Diseases, Mayo Clinic, Rochester, Minnesota, USA*
[3]*Department of Anesthesiology, Mayo Clinic, Rochester, Minnesota, USA*

Abstract

This is the first review of the literature on the effects of slow breathing on glycemic regulation and insulin sensitivity. While many studies have investigated the effects of yoga on individuals with diabetes, few studies have specifically focusing on the isolation of slow breathing as the principle factor in their intervention. While it is difficult to separate the exercise-related effects of yoga, there is considerable evidence that a breathing intervention is capable of increasing insulin sensitivity and improving glycemic regulation. This appears to be true both acutely and chronically in healthy individuals and those with diabetes. Yoga pranayama and the slow breathing practices that are fundamental to yoga represent a relatively low-cost and under-utilized intervention for individuals with conditions related to altered glycemic regulation and insulin sensitivity. More studies should focus on pranayama and slow breathing maneuvers to better clarify the role of respiratory modulation on glucose metabolism and insulin response.

Keywords: Yoga; Glucose; Breathing; Respiration; Metabolism; Diabetes

Introduction

Deep breathing techniques are commonly practiced in the context of traditional yoga exercises that seek to improve cognitive function, leading to mindfulness and stress reduction. While there are many different ways to practice yoga, there are three common themes that arise from the variance: asana, dyana and pranayama. *Asana* is the term used to describe the postural manipulations and poses commonly recognized in yoga. Asana pose duration, physical intensity, environment where asana is performed, and potential of asana to directly or indirectly modify breathing patterns can independently alter human physiology. *Dyana* refers to the meditative aspect of yoga that can alter perception of stress and indirectly alter breathing patterns. *Pranayama* is the attention to breath and conscious manipulation of breathing. There are many yoga subtypes that differ slightly from each other in how asana, dyana, and pranayama practices are performed including Nindra, Iyengar, Hatha, Shavashana and Kundalini, however they all include conscious manipulations of *pranayama* exercises as part of their unique identities [1].

Pranayama breathing exercises are central to yoga and seek to bring the person into the present moment to reduce stress. Some pranayama are fairly complicated and others fairly straightforward, complicating the study of how yoga breathing exercises influence glycemic response and insulin sensitivity. An example of a straightforward pranayama breathing pattern is shown in Figure 1 [2]. This review focuses on how the pranayama aspect of yoga influences insulin sensitivity and glycemic status.

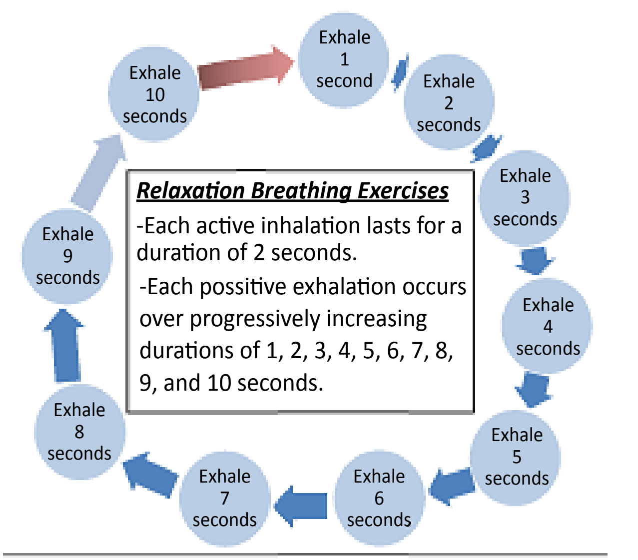

Figure 1: A simple reproducible pranayama relaxation breathing pattern (Wilson et al. [2], reproduced with permission).

Maintenance of insulin and glycemic control is essential for cognitive function, as the brain is an insulin sensitive tissue and is thus affected by impaired insulin control and irregular glycemic response [3]. Additionally, maintenance of glycemic control is especially important during exercise in insulin sensitive tissues such as skeletal and cardiac muscle. Diabetes represents an aberration of glycemic control resulting from an inability to secrete insulin and dependence on exogenous insulin (type 1) or an inability to respond to secreted insulin that may progress into insulin dependence (type 2). In 2013 approximately 9.3% of Americans had diabetes (mostly type 2) and it is predicted that 1 in 3 Americans will develop type 2 diabetes which is associated with a 50% increase in risk of death [4]. In 2012, pharmacological approaches to control diabetes (i.e., insulin, metformin, etc.) cost the United States (US) economy $18 billion out of a total US diabetes cost footprint of $245 billion [5]. Hence, there is a need for less expensive methods

***Corresponding author:** Ted Wilson, Department of Biology, Winona State University, Winona, Minnesota, USA, Tel: 507-457-2485, E-mail: twilson@winona.edu

Received July 03, 2017; **Accepted** July 26, 2017; **Published** July 31, 2017

Citation: Wilson T, Kelly KL, Baker SE (2017) Review: Can Yoga Breathing Exercises Improve Glycemic Response and Insulin Sensitivity? A Clinical Commentary. J Yoga Phys Ther 7: 270. doi: 10.4172/2157-7595.1000270

for diabetes prevention, improved glycemic control in patients with diabetes, and decreased disease complications among individuals with diabetes.

Performance of yoga by individuals with type 2 diabetes has been suggested to lead to improvements in glycemic status in two recent meta-analyses [6,7]. Cui et al. [5] examined 12 randomized controlled trials that included 864 subjects performing yoga exercise sessions 1-6 times week for up to 6 months. They found that both fasting blood glucose and hemoglobin A1c improved as result of yoga by -23.72 mg/dl and -0.47%, respectively. The meta-analysis of Vizcaino et al. [6] contained similar inclusion criteria with less control regarding the duration of the yoga intervention. Their work suggests that fasting blood glucose improvements were greatest in those with the least glycemic control (high baseline HbA1c).

Physical exercise is known to improve insulin sensitivity, glycemic status, weight maintenance and cardiovascular health in individuals with diabetes. There are varying degrees of physical exertion within the many forms of yoga, and these differing degrees of exertion between persons practicing yoga complicate the identification of the source of yoga-dependent improvements in insulin sensitivity and glycemic status. Diabetic comorbidities such as obesity, cardiovascular disease, or arthritis of knees/hips may make it difficult to complete the physical movements/positions of yoga in some persons, however all persons should be able to complete yoga pranayamas [8-11].

Yoga pranayamas may represent a low- or no-cost activity that can improve glycemic status, and may be easier to examine than full yoga practice for effects on insulin sensitivity and glycemic status. The high cost to benefits ratio for improvements in glycemic response and insulin sensitivity among individuals with diabetic observed with pharmacological interventions could make even modest benefits obtained with yoga-based relaxation breathing exercises (pranayama) highly beneficial. Therefore, this review discusses the potential link between pranayama breathing patterns and glycemic control as part of a non-pharmacological intervention in healthy individuals and in individuals with diabetes.

Body

Stress and sympathetic activity as factors affecting glycemic response and insulin sensitivity

Diabetes as a diagnosis is, in its own right, stressful for the patient and reduction of stress is an intended outcome of yoga practice. Stress and the sympathetic response to stress represent factors strongly associated with development of type 2 diabetes [12,13]. Learned stress management techniques can lead to improved glycemic status [13,14]. Yogic pranayama breathing has been suggested to reduce the sense of stress, reduce sympathetic drive, and improve cardiovascular function [15-17]. Lyengar yoga has been suggested to improve mood and anxiety by increasing thalamic GABA levels [18]. Additionally, psychological stress can alter gastrointestinal transit time thereby altering glucose handling [14]. Psychological stress management regimens have also been shown to improve long-term glycemic control [18].

There are important interactions between breathing patterns and the sympathetic nervous system. The respiratory system and sympathetic nervous system are anatomically linked in the brainstem [19-22]. Catecholinergic neurons have been shown to be phase-locked with the respiratory cycle [23]. It then follows that sympathetic outflow to the body is reduced during inspiration, and during expiration the sympathetic nervous system is active [24,25]. Studies using neck pressure to activate sympathetic responses to changes in blood pressure show that these responses are exaggerated during inspiration as opposed to exhalation [26-28]. In addition to acute effects, chronic effects have been observed. For instance, men who breathe faster have increased muscle sympathetic nerve activity [29] and higher breathing rates correlate with higher levels of total peripheral resistance in young men [30]. Furthermore, it has recently been demonstrated that an acute bout of controlled breathing lowers sympathetic activity [31].

Reductions in sympathetic activity through altered breathing patterns can also influence fasting blood glucose. Sympathetic efferent activity in the liver, the main location of glucose production, causes an increase in production of the enzymes responsible for the rate limiting steps for gluconeogenesis [32]. Epinephrine, glucagon and, to a lesser extent, norepinephrine also contribute to increases in hepatic glucose production and release, demonstrating the importance of sympathetic regulation on glucose and fat metabolism [33]. Thus, decreases in respiratory rates can lead to a decrease in stress and sympathetic outflow, ultimately causing a lower rate of gluconeogenesis and glucose release into the blood stream. This could play a role in explaining the improved fasting blood glucose levels typically observed as a result of yoga interventions.

Effect of pranayamas on insulin sensitivity and glycemic status

Alterations in breathing pattern through pranayama can influence insulin sensitivity and glycemic status in healthy individuals and in individuals with diabetes. It is not clear if insulin sensitivity precedes increases in sympathetic outflow, or the other way around [34]. Thus, it is difficult to posit a definitive mechanism as to why the practice of pranayama improves insulin sensitivity. However, reductions in sympathetic activity may have effects on adipose, muscle, and/or pancreatic tissues that lead to improvements in sensitivity and reductions in plasma insulin levels.

A 2008 study comparing insulin sensitivity between practitioners and non-practitioners of acute effects of a bout of yoga or pranayama yoga using a hyperinsulemic-euglycemic clamp concluded that practitioners who practiced yoga for over one year had significantly greater insulin sensitivity and lower fasting insulin levels [35]. However, the study did not look at acute responses to yoga and/or pranayama, and exercise-induced improvements in insulin resistance could have been an underlying cause of the effect. Presumably physical fitness and insulin sensitivity would both be improved by any group of persons who consistently performed a physical exercise routine for one year. In healthy individuals, a 5 day intervention used yoga (asanas/poses) and to a lesser extent yoga breathing maneuvers to improve insulin sensitivity after the administration of an oral glucose tolerance test (OGTT) [36]. Although glucose levels were not significantly lower, insulin levels significantly decreased compared to baseline. However, the pranayama portion of the intervention was poorly described and did not lend itself to easy reproduction in the other clinical investigations. It is also unclear if or how, specific breathing exercises were completed during the asanas.

In a more recent study [2], our group developed a simple and easily reproduced pranayama (relaxation breathing maneuver). We examined the *pranayama* independent of *dyana* and *asana* in 26 healthy college-aged participants (20.1 ± 0.2 years) who acutely practiced the pranayama after an overnight fast just before and during a 75 g oral glucose tolerance test. Participants were randomized to control (no breathing intervention) or relaxation breathing sessions every 10 min for 30 min before the OGTT and every 10 min after OGTT administration.

Citation: Wilson T, Kelly KL, Baker SE (2017) Review: Can Yoga Breathing Exercises Improve Glycemic Response and Insulin Sensitivity? A Clinical Commentary. J Yoga Phys Ther 7: 270. doi: 10.4172/2157-7595.1000270

Compared to the control group, those who performed the breathing maneuvers had significantly lowered blood glucose levels 30 min after OGTT administration (Figure 2). Relaxation breathing resulted in a significantly lower blood glucose 30 min post OGTT administration and the blood glucose AUC for the OGTT approached significance (p=0.09). The study suggests that pranayama, independent or asana and dyana can alter the glycemic and perhaps insulin emic response.

Reductions in post-prandial blood glucose concentrations have been reported in response to chronic yoga and yoga breathing interventions. In a randomized case-control study, those who performed slow breathing, a type of pranayama, for 30 min daily over 8 weeks had decreased post-prandial serum glucose levels [37]. A second study with a lighter regimen of yoga exercises and pranayama (once per week for 12 weeks) also showed significantly reduced post-prandial serum glucose levels compared to a stretching control group [38]. However, the studies did not look at the acute effects of the yoga poses. This means exercise-induced improvements in insulin resistance could have been an underlying cause of the improvement in post-prandial glucose levels.

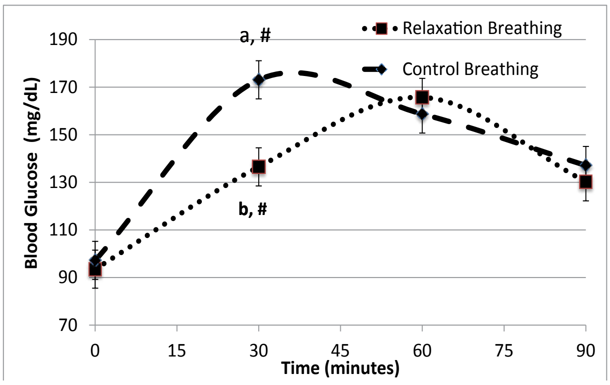

Figure 2: Effect of repeating a relaxation breathing exercise before and immediately following administration of an oral glucose tolerance test (75 g dextrose/240 mL) on the glycemic response of healthy humans.

Data expressed as mean ± standard deviation

Statistical Significance: difference from baseline (0 min) indicated by #, differences between treatments at same time indicated by differing letters. (Wilson et al. [2], used with permission)

In the case of fasting glucose, the responses to a chronic yoga slow breathing regimen in healthy subjects seem to be mixed. In the randomized case-control study mentioned above, 8 weeks of slow breathing induced a reduction in fasting blood glucose levels [37]. A six-day yoga training session however was not sufficient to see reduction in fasting serum glucose levels [39]. This result was supported by a cross sectional study which asked participants about their participation in yoga-related activities, and those who perform yoga activities had similar fasting glucose levels as non-practitioners [40]. A third study found that after an intensive 11 week intervention of hatha yoga for 90 min five times per week, fasting glucose levels rose compared to before intervention [41]. It should be noted that cross-sectional studies cannot prove causation (or lack thereof) and that the intensive hatha yoga study only consisted of 15 subjects. As is apparent from the mixed results above, more work is needed to elucidate the influence of pranayama on fasting glucose levels.

Associations between apneic breathing patterns and diabetes

Sleep apnea represents a pathogenic non-voluntary alteration in the human breathing pattern that is a polar opposite of the pranayama that are practiced in yoga. The breathing patterns found in sleep apnea result in decreased insulin resistance, elevated blood glucose levels, and increased risk for the development of type 2 diabetes [42-44]). In healthy humans, intermittent hypoxia- a model for these apneic episodes- promotes insulin resistance and elevated blood glucose [45]. Newhouse et al. [44] found that fasting blood glucose is elevated within 30 min of exposure to intermittent hypoxia (25 events/h) and remained elevated for the full 3 h of exposure to intermittent hypoxia (Figure 3). Furthermore, patients with sleep apnea who utilize a continuous positive airway pressure (CPAP) device during sleep experienced improvements in insulin sensitivity and glycemic response to an OGTT [46,47]. Given the improvements in insulin sensitivity and glycemic response with CPAP, it is reasonable that yoga pranayama could also be beneficial for persons with sleep apnea. Work is certainly warranted in this area.

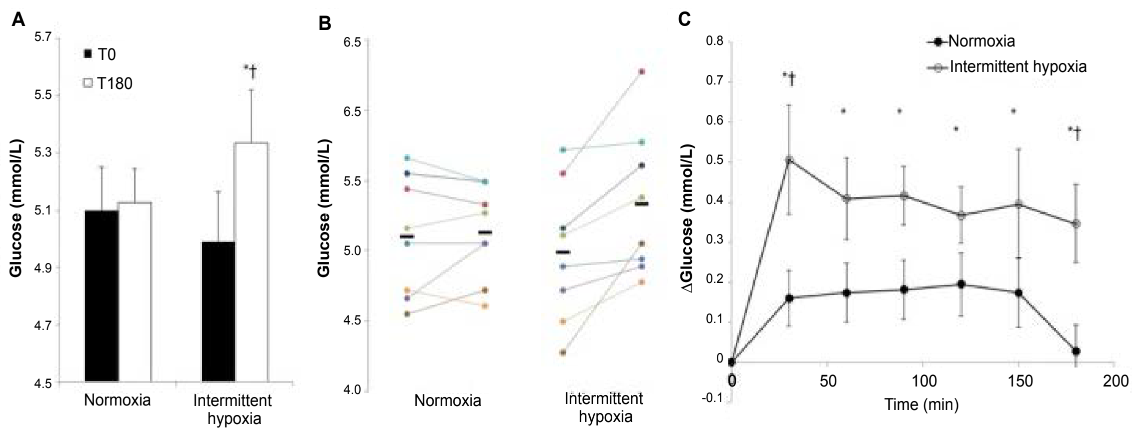

Figure 3: Plasma glucose following 3 h of intermittent hypoxia or continuous normoxia.

Data are reported as Mean ± SEM from *n*=8 (7M/1F). *$P<0.05$ versus T_0. † $P \leq 0.05$ versus Control

A (average data) and B (individual data). Glucose levels were increased by T_{180} on the intermittent hypoxia visit (*$P<0.01$), but no change was observed on the normoxia visit ($P=0.75$). There were no differences in glucose levels between visits at T_0 ($P=0.27$), but there was a difference at T_{180} (†$P=0.051$). (C) Glucose levels remained unchanged during the control visit ($P>0.05$ for all). During the intermittent hypoxia visit, glucose levels were greater than T_0 at all-time points (*$P<0.01$ for all). When data were compared between visits, there was a significant difference at T_{30} (†$P=0.02$) and T_{180} (†$P=0.03$). Newhouse et al. [45], used with permission)

Discussion

Unfortunately the interpretation of yoga RCTs is complicated

Yoga pranayama appears to be beneficial to human health as a whole and, in particular, individuals with type 2 diabetes. In many of the studies outlined above, it is impossible to separate the effects of the various aspects of yoga: stretching, exercise, and slow breathing. In addition to this, the variance between the duration and frequency of intervention vary drastically, leading to conflicting results.

Practices that involve slow breathing, either on its own or in conjunction with complex interventions such as yoga or transcendental meditation may be cost-effective instruments to treating or preventing metabolic syndrome. Those of low socioeconomic status suffer from twofold higher mortality from diabetes [48], and those with lower levels of education are less likely to be participating in yoga [49]. Thus, yoga and/or pranayama may be an appropriate intervention that has been previously untapped in populations with low socioeconomic status. Another population that could be impacted by use of these techniques is men. Men only represent 15.8% of all yoga users [50] and men are more likely to develop diabetes [51]. Thus, yoga may represent a significant health resource that is underutilized by men and individuals with lower socioeconomic status.

Importantly, regardless of physiological outcomes, the use of yoga by people with diabetes leads to improved quality of life and reductions in perceived depression [52].

Limitations

Given the many forms of yoga it is difficult to determine causality contributions of the three elements of yoga: asana, dyana, and pranayama. The many forms of yoga differ with respect to metabolic intensity, meditation goals, and prescribed breathing exercises. Breathing modulation in tandem with exercise complicates interpretation of the results, as exercise by itself is associated with an improved quality of life in individuals with diabetes. Studies of people with diabetes performing yoga are further complicated by the fact that exercise, weight loss and socioeconomics associated with yoga can independently result in improved diabetes outcomes that include glycemic and insulin emic responsiveness. This makes it difficult to give yoga a one-size-fits-all prescription for persons with diabetes, but does not negate the fact that it may be useful low-cost intervention in this population.

Conclusion

Given the high cost of treating disorders related to glycemic response and insulin sensitivity, any small improvements obtained with little to no cost should be part of clinical recommendations. Given the many studies that suggest beneficial effects of yoga for individuals with diabetes and insulin sensitivity, there are very few studies that isolate the effect of just pranayama or slow breathing. Future investigations of yoga benefits for populations with diabetes will need to carefully describe their pranayama and better isolate this effect on glycemic response and insulin sensitivity as part of better patient centered and cost effective diabetes treatment. In addition, studies with an arm focusing exclusively on breathing patterns may be particularly useful in understanding the various aspects of yoga on glucose metabolism.

Acknowledgement

Funding

This publication was made possible by CTSA Grant Number UL1 TR000135 from the National Center for Advancing Translational Sciences (NCATS), a component of the National Institutes of Health (NIH). Its contents are solely the responsibility of the authors and do not necessarily represent the official view of NIH.

Conflict of interest disclosure

Authors do not have any conflicts of interest to disclose.

References

1. Zope SA, Zope RA (2013) Sudarshan kriya yoga: Breathing for health. Int J Yoga 6: 4-10.
2. Wilson T, Baker SE, Freeman MR, Garbrecht MR, Ragsdale FR, et al. (2013) Relaxation breathing improves human glycemic response. J Altern Complement Med 19: 633-636.
3. Ketterer C, Tschritter O, Preissl H, Heni M, Haring HU, et al. (2011) Insulin sensitivity of the human brain. Diabetes Res Clin Pract 93: S47-51.
4. Prevention Cf Dca (2014) National Diabetes Statistics Report. Diabetes Care 36: 1033-1046.
5. Cui J, Yan JH, Yan LM, Pan L, Le JJ, et al. (2016) Effects of yoga in adults with type 2 diabetes mellitus: A meta-analysis. J Diabetes Investig.
6. Vizcaino M (2013) Hatha yoga practice for type 2 diabetes mellitus patients: A pilot study. Int J Yoga Ther 59-65.
7. Way KL, Hackett DA, Baker MK, Johnson NA (2016) The effect of regular exercise on insulin sensitivity in type 2 diabetes mellitus: A systematic review and meta-analysis. Diabetes Metab J 40: 253-271.
8. Liubaoerjijin Y, Terada T, Fletcher K, Boule NG (2016) Effect of aerobic exercise intensity on glycemic control in type 2 diabetes: A meta-analysis of head-to-head randomized trials. Acta Diabetol 53: 769-781.
9. Vinetti G, Mozzini C, Desenzani P, Boni E, Bulla L, et al. (2015) Supervised exercise training reduces oxidative stress and cardiometabolic risk in adults with type 2 diabetes: A randomized controlled trial. Sci Rep 5: 9238.
10. Sigal RJ, Kenny GP, Wasserman DH, Castaneda-Sceppa C, White RD (2006) Physical activity/exercise and type 2 diabetes: A consensus statement from the American Diabetes Association. Diabetes Care 29: 1433-1438.
11. Puig-Perez S, Hackett RA, Salvador A, Steptoe A (2016) Optimism moderates psychophysiological responses to stress in older people with Type 2 diabetes. Psychophysiology.
12. Hilliard ME, Yi-Frazier JP, Hessler D, Butler AM, Anderson BJ, et al. (2016) Stress and A1c among people with diabetes across the lifespan. Curr Diab Rep 16: 67.
13. Surwit RS, van Tilburg MA, Zucker N, McCaskill CC, Parekh P, et al. (2002) Stress management improves long-term glycemic control in type 2 diabetes. Diabetes Care 25: 30-34.
14. Pramanik T, Sharma HO, Mishra S, Mishra A, Prajapati R, et al. (2009) Immediate effect of slow pace bhastrika pranayama on blood pressure and heart rate. J Altern Complement Med 15: 293-295.
15. Veerabhadrappa SG, Baljoshi VS, Khanapure S, Herur A, Patil S, et al. (2011) Effect of yogic bellows on cardiovascular autonomic reactivity. J Cardiovasc Dis Res 2: 223-227.
16. Streeter CC, Whitfield TH, Owen L, Rein T, Karri SK, et al. (2010) Effects of yoga versus walking on mood, anxiety, and brain GABA levels: A randomized controlled MRS study. J Altern Complement Med 16: 1145-1152.
17. Wing RR, Blair EH, Epstein LH, McDermott MD (1990) Psychological stress and glucose metabolism in obese and normal-weight subjects: A possible mechanism for differences in stress-induced eating. Health Psychol 9: 693-700.
18. Zoccal DB, Furuya WI, Bassi M, Colombari DS, Colombari E (2014) The nucleus of the solitary tract and the coordination of respiratory and sympathetic activities. Front Physiol 5: 238.
19. Guertzenstein PG, Silver A (1974) Fall in blood pressure produced from discrete regions of the ventral surface of the medulla by glycine and lesions. J Physiol 242: 489-503.
20. Ross CA, Ruggiero DA, Park DH, Joh TH, Sved AF, et al. (1984) Tonic vasomotor control by the rostral ventrolateral medulla: Effect of electrical or chemical stimulation of the area containing C1 adrenaline neurons on arterial pressure, heart rate and plasma catecholamines and vasopressin. J Neurosci 4: 474-494.
21. Sun QJ, Minson J, Llewellyn-Smith IJ, Arnolda L, Chalmers J, et al. (1997)

Botzinger neurons project towards bulbospinal neurons in the rostral ventrolateral medulla of the rat. J Comp Neurol 388: 23-31.

22. Moraes DJ, da Silva MP, Bonagamba LG, Mecawi AS, Zoccal DB, et al. (2013) Electrophysiological properties of rostral ventrolateral medulla presympathetic neurons modulated by the respiratory network in rats. J Neurosci 33: 19223-19237.

23. Dempsey JA, Sheel AW, St Croix CM, Morgan BJ (2002) Respiratory influences on sympathetic vasomotor outflow in humans. Respir Physiol Neurobiol 130: 3-20.

24. Seals DR, Suwarno NO, Dempsey JA (1990) Influence of lung volume on sympathetic nerve discharge in normal humans. Circ Res 67: 130-141.

25. Eckberg DL, Orshan CR (1977) Respiratory and baroreceptor reflex interactions in man. J Clin Invest 59: 780-785.

26. Eckberg DL, Kifle YT, Roberts VL (1980) Phase relationship between normal human respiration and baroreflex responsiveness. J Physiol 304: 489-502.

27. Eckberg DL, Nerhed C, Wallin BG (1985) Respiratory modulation of muscle sympathetic and vagal cardiac outflow in man. J Physiol 365: 181-196.

28. Narkiewicz K, van de Borne P, Montano N, Hering D, Kara T, et al. (2006) Sympathetic neural outflow and chemoreflex sensitivity are related to spontaneous breathing rate in normal men. Hypertension 47: 51-55.

29. Charkoudian N, Gusman E, Joyner MJ, Wallin BG, Osborn J (2010) Integrative mechanisms of blood pressure regulation in humans and rats: cross-species similarities. Am J Physiol Regul Integr Comp Physiol 298: R755-759.

30. McClain SL, Brooks AM, Jarvis SS (2017) An acute bout of a controlled breathing frequency lowers sympathetic neural outflow but not blood pressure in healthy normotensive subjects. Int J Exerc Sci 10: 188-196.

31. Rui L (2014) Energy metabolism in the liver. Compr Physiol 4: 177-197.

32. Nonogaki K (2000) New insights into sympathetic regulation of glucose and fat metabolism. Diabetologia 43: 533-549.

33. Lambert GW, Straznicky NE, Lambert EA, Dixon JB, Schlaich MP (2010) Sympathetic nervous activation in obesity and the metabolic syndrome--causes, consequences and therapeutic implications. Pharmacol Ther 126: 159-172.

34. Chaya MS, Ramakrishnan G, Shastry S, Kishore RP, Nagendra H, et al. (2008) Insulin sensitivity and cardiac autonomic function in young male practitioners of yoga. Natl Med J India 21: 217-221.

35. Manjunatha S, Vempati RP, Ghosh D, Bijlani RL (2005) An investigation into the acute and long-term effects of selected yogic postures on fasting and postprandial glycemia and insulinemia in healthy young subjects. Indian J Physiol Pharmacol 49: 319-324.

36. Shende V (2013) Effect of pranayama on blood glucose level in medical students: A case control study. Int J Res Health Sci 1: 209-212.

37. Kim SD (2014) Effects of yogic exercises on life stress and blood glucose levels in nursing students. J Phys Ther Sci 26: 2003-2006.

38. Agte VV, Jahagirdar MU, Tarwadi KV (2011) The effects of Sudarshan Kriya Yoga on some physiological and biochemical parameters in mild hypertensive patients. Indian J Physiol Pharmacol 55: 183-187.

39. Younge JO, Leening MJ, Tiemeier H, Franco OH, Kiefte-de Jong J, et al. (2015) Association between mind-body practice and cardiometabolic risk factors: The Rotterdam study. Psychosom Med 77: 775-783.

40. Ramos-Jimenez A, Hernandez-Torres RP, Wall-Medrano A, Munoz-Daw M, Torres-Duran PV, et al. (2009) Cardiovascular and metabolic effects of intensive Hatha Yoga training in middle-aged and older women from northern Mexico. Int J Yoga 2: 49-54.

41. Tiihonen M, Partinen M, Narvanen S (1993) The severity of obstructive sleep apnoea is associated with insulin resistance. J Sleep Res 2: 56-61.

42. Strohl KP, Novak RD, Singer W, Cahan C, Boehm KD, et al. (1994) Insulin levels, blood pressure and sleep apnea. Sleep 17: 614-618.

43. Strand LB, Carnethon M, Biggs ML, Djousse L, Kaplan RC, et al. (2015) Sleep disturbances and glucose metabolism in older adults: The cardiovascular health study. Diabetes Care 38: 2050-2058.

44. Newhouse LP, Joyner MJ, Curry TB, Laurenti MC, Man CD, et al. (2017) Three hours of intermittent hypoxia increases circulating glucose levels in healthy adults. Physiol Rep 5.

45. Salord N, Fortuna AM, Monasterio C, Gasa M, Perez A, et al. (2016) A randomized controlled trial of continuous positive airway pressure on glucose tolerance in obese patients with obstructive sleep apnea. Sleep 39: 35-41.

46. Dorkova Z, Petrasova D, Molcanyiova A, Popovnakova M, Tkacova R (2008) Effects of continuous positive airway pressure on cardiovascular risk profile in patients with severe obstructive sleep apnea and metabolic syndrome. Chest 134: 686-692.

47. Saydha S, Lochner K (2010) Socioeconomic status and risk of diabetes-related mortality in the U.S. Public Health Rep 125: 377-388.

48. Park C, Braun T, Siegel T (2015) Who practices yoga? A systematic review of demographic, health-related, and psychosocial factors associated with yoga practice. J Behav Med 38: 460-471.

49. Ross A, Friedmann E, Bevans M, Thomas S (2013) National survey of yoga practitioners: Mental and physical health benefits. Complement Ther Med 21.

50. Prevention Cf DCa. (2014) Age-Adjusted Rates of Diagnosed Diabetes per 100 Civilian, Non-Institutionalized Population, by Sex, United States, 1980–2014.

51. Satish L, Lakshmi VS (2016) Impact of individualized yoga therapy on perceived quality of life performance on cognitive tasks and depression among Type II diabetic patients. Int J Yoga 9: 130-136.

52. Cai H, Li G, Zhang P, Xu D, Chen L (2016) Effect of exercise on the quality of life in type 2 diabetes mellitus: A systematic review. Qual Life Res.