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Original Article

Comparison of the effect of passive static stretching exercise of upper and lower extremity on blood glucose levels, functional capacity and lipid profile in patients with type 2 diabetes mellitus

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Abstract

Skeletal muscle is non-uniform tissue; in healthy individuals, slow twitch fibers have higher GLUT-4 density compared to fast twitch, and the reverse mechanism occurs in type 2 diabetes mellitus. Stretching exercises of various muscle groups help integrate GLUT-4, which increases metabolic activity and lowers blood glucose levels in patients with type 2 diabetes. Computer generated randomization of 25 participants each into 4 groups, namely Brisk walking (group l), upper limb passive static stretching (group 2), lower limb passive static stretching (group 3) and combined passive static stretching of upper and lower limb (group 4). Stretching exercises were given 4 days/week to corresponding muscle groups for 8 weeks. HbA1C, postprandial blood glucose level (PPBGL), lipid profile and 6-minute walk test were recorded at baseline, after 4 weeks and after 8 weeks of intervention. After 8 weeks of training, HbA1c and postprandial blood glucose levels reduced significantly in upper limb passive static stretching ($p<0.05$) compared to lower limb passive static stretching and control group ($p>0.05$). However, there was an insignificant improvement in lipid profile and 6-minute walk test within and between groups 1, 2, 3 and 4. The decrease in HbA1c and PPBGL levels following 8 weeks of stretching indicates that upper limb stretching had a higher impact on glucose clearance than lower limb stretching in type 2 diabetes.

Keywords: type 2 diabetes, blood glucose level, static stretching exercise, brisk walking.

Introduction

Diabetes mellitus is one of the largest global health emergencies of this century [1]. According to WHO, non-communicable diseases accounted for 74% of deaths globally in 2019, of which diabetes resulted in 1.6 million deaths, thus becoming the ninth leading cause of death globally [1]. The incidence and prevalence of type 2 diabetes mellitus vary according to geographical region, with more than 80% of patients living in low to middle-income countries, which poses additional challenges to ineffective treatment [2]. Type 2 diabetes can result in multiorgan complications that can be roughly categorized as microvascular and macrovascular problems. Good control of blood sugar, blood pressure and lipid levels can prevent or delay the onset of diabetes complications [1–6].

Physical activities improve tissue sensitivity and glycemic control in patients with diabetes mellitus. Exercise produces short and long-term consequences that affect the level of HbA1c, blood glucose level, blood pressure and serum lipid profile. Several studies have shown a significant effect of aerobic exercise and resistance exercise and a combined effect of both on reducing blood glucose levels [7–10]. However, many diabetic patients can not achieve the recommended levels of physical activity due to the occurrence of different diabetic complications, and most of the patients are elderly people who lack sufficient physical work capacity to perform aerobic and resistance exercises. Passive static stretching can be advantageous for patients who are bedridden and cannot perform active movements. Thus, passive stretching exercise has the potential to provide an alternative treatment modality in the absence of a patient's desire to exercise [11, 12].

Several studies have shown that active and passive stretching exercises help lower blood glucose levels in individuals with type 2 diabetes [11–19].

There is a difference in glucose clearance and insulin sensitivity between upper limb and lower limb muscles in individuals with type 2 diabetes mellitus [20]. GLUT-4 protein density varies with types of muscle fibers, as slow twitch muscle fibers have higher GLUT-4 density than fast twitch muscle fibers in healthy individuals [21–23]. In contrast, GLUT-4 density in individuals with type 2 diabetes is higher in fast-twitch muscle fibers than slow-twitch muscle fibers [24]. As there is a higher proportion of fast twitch muscle fibers in the upper body in individuals with type 2 diabetes mellitus, this underlies the reason that glucose clearance is higher in arm muscles than in the leg muscle in this population.

In previous studies [11–19], no definitive conclusion could be drawn for framing a definitive protocol of stretching exercises in patients with type 2 diabetes mellitus due to multiple limitations in all the studies like insufficient sample size, limited to male gender only, less than three stretching sessions per week, lack of proper outcome measures and long trial interventions were not performed to determine the improvement in glycemic control. Also, all of these studies [11–19] employed an intervention protocol comprising stretching a heterogeneous group of muscles; that is, both upper limb and lower limb muscles were being stretched together. These studies have ignored the physiological difference between the upper and lower extremity muscle groups regarding glucose clearance in individuals with type 2 diabetes [20].

Thus, the present study investigated the effect of eight weeks of passive static stretching of muscles of the upper and lower extremities on postprandial blood glucose level, glycosylated hemoglobin level (HbA1c), functional capacity (6-minute walk test) and lipid profile in patients with type 2 diabetes mellitus in order to

Table 1: Stretching exercise protocol.

Group 1 (Control group)	**Group 2 (Upper limb passive static stretching)**	**Group 3 (Lower limb passive static stretching)**	**Group 4 (Combined passive static stretching of the upper and lower limb)**
Oral hypoglycemic drugs and brisk Walking for 20 minutes	Passive static stretching of upper limb muscles + Oral hypoglycemic drugs + brisk walking for 20 minutes. Upper limb muscles: 1. Trapezius 2. Biceps brachii 3. Triceps brachii 4. Pectoralis major 5. Wrist flexors Repetitions: 4 Stretch hold period: 30 sec. Relaxation period: 10 sec. Rest period between Different stretch: 30 sec.	Passive static stretching of lower limb muscles + Oral hypoglycemic drugs + brisk walking for 20 minutes. Lower limb muscles: 1. Quadriceps 2. Hamstring 3. Calf 4. Glutei 5. Hip adductors Repetitions: 4 Stretch hold period: 30 sec. Relaxation period: 10 sec. Rest period between Different stretch: 30 sec.	Passive static stretching of both upper and lower limb muscles + Oral hypoglycemic drugs + brisk walking for 20 minutes. Muscles of the upper limb and lower limb: 1. Trapezius 2. Biceps brachii 3. Triceps brachii 4. Pectoralis major 5. Wrist flexors 6. Quadriceps 7. Hamstring 8. Calf 9. Glutei 10. Hip adductors Repetitions: 4 Stretch hold period: 30 sec. Relaxation period: 10 sec. Rest period between Different stretch: 30 sec.
Frequency of session – 4 days/week; Duration of treatment – 8 weeks; A total of 32 sessions of treatment were given to each participant.			

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establish a definite stretching protocol in these individuals.

Material and methods

Study design and recruitment of participants

This study was a prospective randomized control trial approved by the institutional ethics committee (letter No. BREC/22/338) and registered in the Clinical Trials Registry India (CTRI/2023/04/052099). Patients clinically diagnosed with type 2 diabetes mellitus, age group 20–65 years, who were on oral hypoglycemic drugs, with a history of more than 6 months of diabetes and confirmed by hba1c level 6.5% or higher as a criterion for diagnosis of diabetes were recruited from Medicine department, Pt. B.D. Sharma PGIMS, Rohtak. Patients diagnosed with unstable cardiovascular conditions, patients who were not willing to participate, patients diagnosed with any musculoskeletal conditions such as fracture, muscular pain, or hypermobile joints, which may affect the physical activity of upper and lower extremity, patients diagnosed by a physician with mental illness, psychiatric disorder, cognitive impairments and patients who are having problems with comprehension were excluded.

A total of 100 participants who met the inclusion criteria were randomly allocated using a generated randomization list to four groups: control group (Group 1), Upper limb passive static stretching group (Group 2), Lower limb passive static stretching group (Group 3) and Combined passive static stretching of upper and lower limb (Group 4), with 25 participants in each group. Informed consent was obtained from all the participants in English and Hindi.

Intervention

Demographic data was recorded for the participants before the commencement of the stretching exercise program, including Age and Gender. Measurements of HbA1c, postprandial blood glucose level, lipid profile and 6-minute walk test variables were obtained before the commencement of intervention (PRE) and repeated after four weeks (POST-1) and after eight weeks (POST-2) of intervention. Intervention (Table 1) was continued four times weekly for 8 weeks. A total of 32 treatment sessions were given to each participant in 8 weeks.

Outcome measures

Blood glucose levels were measured by glucometer, and a 6-minute walk test was recorded on a 6-minute walk test recording sheet. Glycosylated hemoglobin and lipid profile (cholesterol, triglyceride, HDLC) levels were measured in the PGIMS laboratory.

Statistical analysis

Statistical analysis was performed using SPSS software 27.0 for the Windows version. The significance of the difference in proportions of qualitative demographic variables expressed as proportions and percentage was inferred by the Chi-square test ($p<.05$), and the significance of the difference in mean values of qualitative data expressed as mean±S.D. was inferred by one way ANOVA ($p<.05$). Data analysis and comparison for within-group and between-group differences of various outcome measures was done using one-way ANOVA and post hoc analysis with Duncan's multiple range test. A p-value of ≤0.05 was taken as a significant difference for all statistical tests.

Results

Table 2 compares baseline characteristics between Group 1, Group 2, Group 3 and Group 4. At baseline, there was a non-significant difference between all four groups for the participants' age and gender.

Table 3 shows that there was a significant reduction in HbA1c mean values at POST-3 (after the 8^{th} week) time

Table 2: Demographic characteristics of the patients.

Sr no.	Characteristics		Group 1	Group 2	Group 3	Group 4	P-value
1	Mean age (years)		54.00±10.42	53.88±6.57	55.32±8.12	48.84±9.75	.06 ^{NS}
2	Gender	Male	11 (44%)	9 (36%)	15 (60%)	11 (44%)	.31 ^{NS}
		Female	14 (56%)	16 (64%)	10 (40%)	14 (56%)	

Note: ^{NS} – non-significant difference.

Table 3: Comparison in and between Group 1, Group 2, Group 3 and Group 4 for HbA1c, postprandial blood glucose level.

Variables	Groups	Mean±SD PRE (baseline)	POST-1 (after 4 weeks)	POST-2 (after 8 weeks)	F-value	P-value
HbA1c	Group 1	8.97±2.66	9.07±2.48	9.11±2.32	.02	.98NS
	Group 2	8.52±1.71	8.12±1.74	7.32±1.61	3.25	.04*
	Group 3	8.98±2.30	8.66±2.31	8.48±2.22	.31	.73 NS
	Group 4	9.42±2.51	8.86±2.47	7.75±2.01	3.29	.04*
	Between groups	.60 NS	.49 NS	.01 #		
PPBGL	Group 1	273.52±97.81	235.60±73.76	236.20±77.80	1.68	.19NS
	Group 2	220.20±46.86	160.88±47.88	129.88±18.34	32.73	.001*
	Group 3	238.12±72.93	182.88±48.75	167.00±38.14	11.42	.001*
	Group 4	248.16±71.94	178.40±42.65	140.96±23.50	29.41	.001*
	Between groups	.09 NS	.<001 #	.<001 #		

Note: NS – non- significant difference; * – significant difference in within group; # – significant difference in between groups.

interval as compared to PRE time interval (before intervention) both in group 2 and group 4. However, there was no significant difference between HbA1c mean values recorded at PRE, POST-1 and POST-2 time intervals ($p>0.05$) within group 1 and group 3. There was a significant reduction in HbA1c level between Group 1, Group 2, Group 3 and Group 4 after 8 weeks of intervention. There was a significant reduction in PPBGL mean values at POST-3 (after the 8th week) time interval as compared to PRE (before intervention) PPBGL mean values in group 2, group 3 and group 4. There was a significant reduction in PPBG level between Group 1, Group 2, Group 3 and Group 4 after 4 weeks of intervention.

Table 4 shows that there was insignificant improvement in cholesterol, triglyceride, high-density lipoprotein and 6-minute walk test in patients with type 2 diabetes mellitus after 8 weeks of intervention within and between Group 1, Group 2, Group 3 and Group 4.

Discussion

The study's aim was to compare the effect of upper extremity and lower extremity passive static stretching exercises on postprandial blood glucose level, glycosylated hemoglobin level (HbA1c), functional capacity and lipid profile in patients with type 2 diabetes mellitus. The findings showed the beneficial effect of passive static stretching exercise of upper limb muscles in patients with type 2 diabetes mellitus.

HbA1c level and postprandial blood glucose level

There was a significant reduction in HbA1c mean values in group 2 (passive static stretching of upper limb muscles) and group 4 (combined passive static stretching of upper and lower limb muscles) as compared to group 1 (brisk walking) and group 3 (passive static stretching of lower limb muscles) after 8 weeks of intervention. There was a highly significant difference between PPBGL levels ($P<0.01$) within group 2, group 3 and group 4 as compared to group 1(control group).

The present study's results are supported by previous studies' findings [14, 16, 19], which investigated the effects of passive static stretching on blood glucose levels in patients with type 2 diabetes mellitus. A study by Park *et al*. concluded that the HbA1c level decreased significantly in the passive static stretching group after eight weeks of intervention [14]. The results of the present study also agree with another previous study done by Elgayar *et al*., who concluded that HbA1c levels decreased significantly in both active stretching and passive stretching groups with no difference between them [16]. Another recent study by Shagun *et al*. reported that HbA1c levels reduced significantly ($p>.0001$) after twelve weeks of intervention [19]. The result of this study is also supported by the result of Nelson *et al*., who concluded that passive static stretching of the skeletal muscle may be an alternative to exercises to help lower the blood glucose level [11].

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Table 4: Comparison within and between Group 1, Group 2, Group 3 and Group 4 for lipid profile and 6-minute walk test.

Variables	Groups	Mean±SD PRE (baseline)	POST-1 (after 4 weeks)	POST-2 (after 8 weeks)	F-value	P-value
Cholesterol	Group 1	198.86±41.62	200.16±35.89	200.61±33.93	.01	.98 NS
	Group 2	193.54±50.68	188.84±44.70	182.52±37.83	.38	.68 NS
	Group 3	179.50±57.84	175.46±45.70	171.50±36.22	.18	.83 NS
	Group 4	207.62±56.28	201.64±53.64	194.99±53.54	.33	.71 NS
	Between groups	.28 NS	.15 NS	.06 NS		
Triglyceride	Group 1	201.36±88.85	200.07±76.69	197.26±61.59	.02	.98 NS
	Group 2	250.80±109.46	230.17±84.55	213.31±65.87	1.12	.33 NS
	Group 3	207.77±88.98	192.01±68.66	177.85±62.36	1.01	.36 NS
	Group 4	233.85±110.95	214.41±100.22	196.89±87.23	.85	.42 NS
	Between groups	.27 NS	.39 NS	.36 NS		
HDLC	Group 1	43.02±10.39	43.10±9.64	43.41±8.77	.01	.99 NS
	Group 2	38.70±9.79	39.62±9.28	40.61±9.08	.26	.77 NS
	Group 3	39.67±11.20	40.45±9.90	41.41±9.07	.18	.83 NS
	Group 4	42.48±11.06	43.55±10.88	44.67±10.81	.25	.78 NS
	Between groups	.40 NS	.41 NS	.41 NS		
6-minute walk test	Group 1	1476.00±212.19	1476.40±212.15	1491.20±216.11	.04	.96 NS
	Group 2	1497.20±200.82	1534.40±201.22	1586.00±205.04	1.21	.30 NS
	Group 3	1505.60±262.13	1550.80±264.35	1613.60±264.17	1.05	.35 NS
	Group 4	1602±397.38	1679.60±399.74	1778.40±397.55	1.23	.29 NS
	Between groups	.39 NS	.07 NS	.005 #		

Note: NS – non-significant difference; * – significant difference in within group; # – significant difference in between groups.

This study agreed with Solomen *et al.*, who suggested that active and passive skeletal muscle stretching may be alternatives to resistance exercises to lower blood glucose levels. Also concluded that passive stretching was better than active stretching exercise in reducing the blood glucose level [13]. This is in accordance with Gurudut *et al.*, who concluded that passive static stretching and resistance exercise both effectively reduce postprandial blood glucose levels in type 2 diabetes and must be prescribed for patients who demonstrate difficulty in controlling postprandial spikes [15]. This study is also supported by Taheri *et al.*, who indicated that passive stretching significantly reduced immediate blood glucose levels after training in type 2 diabetic patients [12]. This study is in accordance with Mehta *et al.*, who reported that both strengthening and stretching exercises are effective in decreasing postprandial blood glucose levels in type 2 diabetic patients, as there is no significant difference between them [17]. This study was supported by Shirodkar *et al.*, who concluded that static stretching effectively reduced blood sugar levels and improved quality of life in subjects with type 2 diabetes mellitus [18].

There are several possible mechanisms as to why blood glucose level has decreased: Passive stretching of skeletal muscle increases heat production and oxygen consumption. Mechanical stimuli such as stretch increase glucose transport and glycogen metabolism in stretched skeletal muscle. The glucose transport is primarily mediated by glucose transport protein, GLUT-4, and exercise can increase GLUT-4 levels in skeletal muscle. A single stretch increases the nitric oxide level by up to 20% during stretching. Nitric oxide also affects GLUT-4 inclusion. The ischemia due to static stretching also makes it easier for GLUT-4 to go into the sarcolemma. The integration of GLUT-4 into the stretched muscle enhances metabolic activity and reduces the blood glucose level. Additional research on static stretching shows static stretching promotes the protein kinase B activity, which enhances glucose uptake by skeletal muscle cells and lowers the blood glucose level [11–19].

In this study, patients who underwent passive static stretching of the upper limb muscles, as well as a combination of passive static stretching exercises for both upper and lower extremities, showed greater improvement in glycemic control compared to those who only underwent passive static stretching of the lower limbs. This difference can be attributed to the fact that the same tissue in different body areas is not metabolically identical. The composition of muscle fiber types plays a role in the varying insulin sensitivity between arm and leg muscles. In type 2 diabetes, the density of GLUT4 has been found to be higher in fast-twitch muscle fibers compared to slow-twitch fibers. A higher proportion of fast type II muscle fibers in the upper body could have preserved glucose uptake. Another possible explanation for the difference in arm and leg insulin sensitivity found could result from a difference in vascular responsiveness between the upper and lower limbs. That is, arm vasodilator response compared to leg is higher to both pharmacological and physiological vasodilator stimuli. The findings of the present study are supported by the result from a previous study conducted by Olsen DB *et al.*, who stated that glucose clearance is higher in arm muscles than leg muscles in type 2 diabetes mellitus [20].

Lipid profile level

In this study, there was an insignificant improvement in lipid profile (total cholesterol, triglyceride, HDLC) in patients with type 2 diabetes mellitus after 8 weeks of intervention in Group 1 (Control group), Group 2 (passive static stretching exercise of upper limb muscles), Group 3 (passive static stretching exercise of lower limb muscles) and Group 4 (combined static stretching exercise of upper and lower limb muscles). There was insignificant improvement between group 1, group 2, group 3 and group 4 at baseline, after the 4th week and after 8th week time interval.

The result of this study is supported by Yildirim *et al.*, who identified that eight weeks of regular exercises affected the body components positively but produced no effect on the lipid profile of sedentary young women [25]. The study conducted by Szapary PO *et al.* concluded that the combination of aerobic and resistance training might be an optimal combination to improve serum lipoprotein [26]. When adherence is achieved, the improvement in sedentary patients with dyslipidemia occurs with resistance exercise, the combination of strength and resistance, and diet and physical activity recommendations [27]. The study conducted by Ouerghi N *et al.* concluded that an eight-week high-intensity interval training program resulted in a slight improvement in physical fitness and a significant decrease in plasma lipids in obese subjects but not in normal-weight subjects [28]. Koubaa *et al.* observed an improvement in plasma lipids after 12 weeks of interval training in obese children [29]. Racil G *et al.* observed an improvement in plasma lipid, cardiometabolic variables, blood leptin concentration and rating of perceived exertion after a 12-week high-intensity interval training program in adult obese females [30].

Six-minute walk test

There was insignificant improvement in the 6-minute walk test in patients with type 2 diabetes mellitus after 4th week and 8 weeks of intervention in Group 1 (Control group), Group 2 (passive static stretching exercise of upper limb muscles), Group 3 (passive static stretching exercise of lower limb muscles) and Group 4 (combined static stretching exercise of upper and lower limb muscles). There was an insignificant improvement in the 6-minute walk test between Group 1, Group 2, Group 3 and Group 4 at baseline, after 4th week and after 8th week time interval. The six-minute walk test is an outcome measure used to evaluate the functional capacity of patients with type 2 diabetes mellitus. The six-minute walk test is a measure of functional capacity, which requires a longer period to develop, as demonstrated in a previous study by Elagyar *et al.* (2019). Their study, Active *versus* Passive Stretching Exercises on Blood Glucose and Functional Capacity in Elderly Diabetic Patients, concluded that significant improvements in blood glucose levels and functional capacity were observed after 12 weeks of intervention [16]. Similarly, a study by Pérez FJ *et al.* found a highly significant improvement in the six-minute walk test following a 4-month moderate exercise program in sedentary patients with cardiovascular risk factors [27].

The study's limitations were as follows: Given that the lipid profile reflects fat molecules in the blood, the 8-week study period may have been too short to observe significant changes resulting from stretching. Additionally, no follow-up measurements were conducted.

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Furthermore, an eight-week intervention period may be insufficient to fully assess changes in functional capacity attributable to passive static stretching.

This study has clinical application. Static stretching can be given to patients who are bedridden for longer periods of time and have high blood sugar levels, which are difficult to control, and people of the geriatric age group who are not able to perform aerobic and resistance exercises. Stretching can aid in reducing blood sugar levels, with passive static stretching of the upper limb muscles proving more effective than stretching exercises for the lower limbs. Both approaches contribute to lowering high blood sugar levels and could be clinically applied to hospitalized patients.

Further studies are required to ascertain the long-term (more than 2 months) effects of passive static stretching on the lipid profile and functional capacity of patients with type 2 diabetes mellitus. This study could also be repeated to evaluate the long-term effects of the exercises, specifically during the fasting period. Research should also address the possible additive benefits of combined stretching with either aerobic or resisted exercises.

Conclusion

Passive static stretching of upper limb muscles is more beneficial in reducing blood glucose levels than passive static stretching of lower limb muscles in patients with type 2 diabetes mellitus. Furthermore, in light of the outcome measure of the present research, we proposed that passive static stretching exercises of upper limb muscles should be included in the rehabilitation protocol of patients with type 2 diabetes mellitus.

Conflict of interest

The authors declare no conflict of interest.

References

1. Pradeepa R, Mohan V. Epidemiology of type 2 diabetes in India. Indian J Ophthalmol 69:2932-38, 2021.
2. Galicia-Garcia U, Benito-Vicente A, Jebari S et al. Pathophysiology of type 2 diabetes mellitus. Int J Mol Sci 21(17):6275, 2020.
3. Nagarathna R, Bali P, Anand A et al. Prevalence of diabetes and its determinants in the young adults indian population-call for yoga intervention. Front Endocrinol 11, 2020.
4. American Diabetes Association. Diagnosis and classification of diabetes mellitus. Diabetes care 31(Supplement_1):S62-7, 2008.
5. American Diabetes Association. Diagnosis and classification of diabetes mellitus. Diabetes care 33(Supplement_1):S62-9, 2010.
6. American Diabetes Association. Diagnosis and classification of diabetes mellitus. Diabetes care 37(Supplement_1):S81-90, 2014.
7. Kirwan JP, Sacks J, Nieuwoudt S. The essential role of exercise in the management of type 2 diabetes. Cleve Clin J Med 84(7 Suppl 1):S15-S21, 2018.
8. Sato Y. Overview of exercise prescription for diabetes patients and its application in Japan. SSEJ 2(3):226-35, 2020.
9. Fajriyah N, Sudiana IK, Wahyuni ED. The effects from physical exercise on the blood glucose levels, HbA1c and quality of life of type 2 diabetes mellitus patients: A systematic review. Jurnal Ners 15(2):486-96, 2020.
10. Colberg SR, Sigal RJ, Fernhall B et al. Exercise and type 2 diabetes: the American College of Sports Medicine and the American Diabetes Association: joint position statement. Diabetes care 33(12):e147-67, 2010.
11. Nelson AG, Kokkonen J, Arnall DA. Twenty minutes of passive stretching lowers glucose levels in an at-risk population: an experimental study. J Physiother 57(3):173-78, 2011.
12. Taheri N, Mohammadi HK, Ardakani GJ, Heshmatipour M. The effects of passive stretching on the blood glucose levels of patients with type 2 diabetes. J Bodyw Mov Ther. 2018.
13. Solomen S, Shakya R, Agarwal K, Aaron P, Pradeep S. Passive stretching versus active stretching on immediate blood glucose in subjects with type II diabetes mellitus-A pilot study. IJPESH 2(1):146-49, 2015.
14. Park SH. Effects of passive static stretching on blood glucose levels in patients with type 2 diabetes mellitus. J Phys Ther Sci 27(5):1463-65, 2015.
15. Gurudut P, Rajan AP. Immediate effect of passive static stretching versus resistance exercises on postprandial blood sugar levels in type 2 diabetes mellitus: a randomized clinical trial. JER 13(5):581-87, 2017.
16. Elgayar SL, Hagag AA, Ghazi HA. Active versus Passive Stretching Exercises on Blood Glucose and Functional Capacity in Elderly Diabetic Patients: Comparative Study. IOSR-JNHS 8(2):61-7, 2019.
17. Mehta SM, Patil S. Immediate Effect of Stretching Versus Strengthening Exercises on Blood Glucose Level in Chronic Diabetes Mellitus. IJFMTS 14(3):681-86, 2020.
18. Shirodkar S, Deo M, Agnihotri M, Epte R. Effect of Static Stretching on Random Blood Sugar Levels in Type 2 Diabetes Mellitus: A Randomized Clinical Trial. IJHSR 12(7):156-62, 2022.
19. Agarwal S, Sethi J, Aggrawal R. Effect of proprioceptive neuromuscular facilitation stretching versus aerobic training on glycosylated hemoglobin (HbA1C) in patients with type 2 diabetes mellitus. J med Pharm Allied Sci 11(4):5124-27, 2022.
20. Olsen DB, Sacchetti M, Dela F, Ploug T, Saltin B. Glucose clearance is higher in arm than leg muscle in type 2 diabetes. J Physiol 565(2):555-62, 2005.
21. Goodyear LJ, Hirshman MF, Smith RJ & Horton ES. Glucose transporter number, activity, and isoform content in plasma membranes of red and white skeletal muscle. Am J Physiol 261, E556–E561, 1991.
22. Gaster M, Poulsen P, Handberg A, Schroder HD & Beck-Nielsen H. Direct evidence of fiber type-dependent GLUT-4 expression in human skeletal muscle. Am J Physiol 278, E910–E916, 2000.

23. Daugaard JR & Richter EA. Muscle- and fibre type-specific expression of glucose transporter 4, glycogen synthase and glycogen phosphorylase proteins in human skeletal muscle. Pflugers Arch 447, 452–456, 2004.
24. Gaster M, Staehr P, Beck-Nielsen H, Schrøder DD & Handberg A. GLUT4 is reduced in slow muscle fibers of type 2 diabetic patients: is insulin resistance in type 2 diabetes a slow, type 1 fiber disease? Diabetes 50, 1324–1329, 2001.
25. Yildirim I, Aydin Altinbas M, Demirezen NB, Dener S, Sezgin V. The effect of different exercise types on sedentary young women's lipid profile. J Back Musculoskelet Rehabil 33(3):469-75, 2020.
26. Szapary PO, Bloedon LT, Foster GD. Physical activity and its effects on lipids. Current Cardiolo Rep 5(6):488-93, 2003.
27. Pérez FJ, Bonafonte LF, Guerediaga DI, Belaza MP, Peyron PU. Effect of an individualised physical exercise program on lipid profile in sedentary patients with cardiovascular risk factors. Clínica e Investigación en arteriosclerosis (English edition) 29(5):201-8, 2017.
28. Ouerghi N, Fradj MK, Bezrati I et al. Effects of high-intensity interval training on body composition, aerobic and anaerobic performance and plasma lipids in overweight/obese and normal-weight young men. Biol sport 34(4):385-92, 2017.
29. Koubaa A, Trabelsi H, Masmoudi L et al. Effect of intermittent and continuous training on body composition cardiorespiratory fitness and lipid profile in obese adolescents. IOSR-JPBS 3(2):31-7, 2013.
30. Racil G, Ben Ounis O, Hammouda O et al. Effects of high vs. moderate exercise intensity during interval training on lipids and adiponectin levels in obese young females. Eur J Appl Physiol 113(10):2531-2540, 2013.

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