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REVIEW

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Effects of exercise on blood pressure and arterial stiffness in patients with type 2 diabetes mellitus: a literature review

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ABSTRACT

Introduction: Diabetes mellitus type 2 increases the mortality and the risk of premature morbidity related to cardiovascular disease. High blood pressure stands out as the main morbidity in this diabetic patient and arterial stiffness by one of the common complications associated with the disease, both of which can precipitate the occurrence of vascular disorders. In this context, the physical exercise is considered an important component in the treatment of these patients, as it helps in the control of cardiovascular risk factors. **Objective:** To investigate the effects of the physical exercise on pressure and arterial stiffness in patients with type 2 Diabetes mellitus. **Methods:** This is a literature review conducted in the period March-April 2015 in MEDLINE, LILACS, SciELO, PubMed and Cochrane databases. The keywords used were "Type 2 Diabetes Mellitus", "Exercise", "Arterial Stiffness" and "Arterial Pressure", combined by the boolean operator "and" being considered for this review only studies published between 2009 and 2015. **Results:** A total of 146 publications, were select 8 studies that investigated the effects of physical exercise on blood pressure and arterial stiffness in patients with type 2 Diabetes mellitus. Of these, 6 studies investigated the effects of physical exercise on blood pressure, which was completed in 4 of them, that it was effective in promoting protective effects of blood pressure. With respect to arterial stiffness, analyzed in four studies, it was found that aerobic training was able to generate reductions in their values after 3 months of intervention, which however were not maintained after longer periods. **Conclusion:** The physical exercise can be appointed as a promising strategy for arterial pressure control in patients with diabetes mellitus type 2. With regard to arterial stiffness, it is assumed that structural vascular changes manifested in the disease process present irreversible characteristics and therefore can not be modified even after long periods of intervention.

Keywords: Type 2 Diabetes Mellitus, Exercise, Arterial Stiffness and Arterial Pressure.

INTRODUCTION

Diabetes mellitus (DM) is a group of metabolic diseases characterized by hyperglycemia resulting from disorders of insulin action, due to the destruction of the pancreatic beta cells, called type 1 DM, and/or by deficiency in insulin secretion and resistance, called DM Type 2, the most prevalent.[1,2]

The main risk factors associated with type 2 DM include genetic predisposition, obesity, sedentary lifestyle, hypertension, advanced age and high rate of capillary glycemia. These factors, coupled with the increase in population aging, greater urbanization and survival of diabetic patients, have increased the number of cases of the disease.[3,4]

Data from 2013 indicate that there are 382 million adults with DM worldwide, with a projection of more than 592 million cases in 25 years, with type 2 DM present in 85-95% of cases in high-income countries, with percentages even higher for low- and middle-income countries. In Brazil, the estimates were of 11.9 million cases in 2013, reaching the number of 19.2 million cases for the year 2035.[5]

The classical form of DM 2, distinguished by the combination of insulin resistance and failure of the pancreatic beta cells in maintaining the adequate secretion of its hormone, has gradual mechanisms of disease development. Initially, for glucose metabolism control and insulin resistance compensation, there is an increased production of total beta cell (β) as well as the production and secretion of insulin. Subsequently, there is a failure in this compensatory mechanism, triggering the evolution of the disease with preservation of blood glucose levels above the values considered normal.[4,6]

The holder of type 2 diabetes have high risk of mortality and development of premature morbidity related to

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cardiovascular disease, disorders in vision, kidney problems, in the peripheral nerves and amputations. In 2013, for DM mortality rate in Brazil was 124.687 thousand inhabitants for individuals aged between 20 and 79 years.[4,5,7] In this context, it is possible to emphasize arterial hypertension as the main morbidity in this diabetic patient, characterized by promoting the development and progression of micro and macrovascular complications. Thus, the adequate control of blood pressure (BP) is able to reduce up to 76% cardiovascular mortality in patients with type 2 DM and may be more effective than the glycemic control.[8,9]

Individuals with type 2 DM also are more susceptible to structural and functional changes of their arteries. Diabetics have stiffer central and peripheral arteries when compared with non-diabetic subjects, which may contribute to the precipitation of atherosclerotic processes and their vascular complications.[10]

In addition, physical inactivity has been identified as the main fourth risk factor for overall mortality, totaling 6% of these deaths, increasing prevalence of chronic non-communicable diseases (NCDs), including the DM, which is responsible for approximately 27% of cases. The increasing number of cases of type 2 DM and consequent exacerbation of patients with complications caused by the disease, leads to efforts not only to combat it, but also to reduce the problems resulting from it.[11,12]

Scientific evidence shows that regular physical exercises reduce the risk of developing NCDs, being an important component for the appropriate body energy balance. For disease already established, it has been well documented in improving insulin sensitivity and glycemic control; reducing the use of hyperglycemia-related drugs; on glucose transporters (GLUT-4 protein) due to muscle contractions; decreased visceral adiposity and cardiovascular risk through decreasing blood pressure, obesity and blood lipid profile.[11,12]

Given the above, this review aims to highlight the scientific evidences related to the influence of exercise on the pressure and arterial stiffness in patients with type 2 DM.

METHOD

Study Characterization and search strategy

This research is characterized as a literature review and was carried out from March to April 2015 in five databases, namely: the U.S. National Library of Medicine (NLM) bibliographic database (MEDLINE), Latin-American and Caribbean System on Health Sciences Information (LILACS), Scientific Electronic Library Online (SciELO), PubMed and Cochrane. It was used the following descriptors in this review: "Type 2 Diabetes Mellitus", "Exercise", "Arterial Stiffness" and "Arterial Pressure", combined using the boolean operator "and". The selected studies included only written in English, Spanish and Portuguese, only published in January 2009 to April 2015.

Inclusion and exclusion criteria

The criteria for inclusion of studies were: original articles of controlled randomized clinical trials based on the application of resistance and/or aerobic training programs and its effects on blood pressure and arterial stiffness in individuals with type 2 DM. Exclusion criteria were: studies performed in animals, with focus on gestational diabetes, which did not have full text available in electronic form and/or that recurred in the databases.

RESULTS

It was found 146 publications between the period from January 2009 to April 2015, all written in English, Spanish or Portuguese. The first stage of selection of items was made by reading the titles and abstracts, where non-original studies of randomized controlled clinical trials were excluded; which did not apply resistance training programs and/or aerobic or did not evaluate its effects on the pressure and arterial stiffness in patients with type 2 DM, leaving 18 studies. In the second step, the complete reading of the text was made, which were selected 8 studies, 7 written in English and 1 in Portuguese. From 18 studies, 10 were excluded due to be duplicated in the databases. In total, it was excluded 138 articles because they did not fulfill the criteria for inclusion in this review (figure 1). The 8 included studies are briefly described in table 1.

It was selected six studies which investigated the effect of exercise on BP in patients with type 2 DM.[13,14,15,16,17,18] Thus, all the research presented here are accord to the inclusion criteria and are limited to the analysis of the effects of exercise in people diagnosed with type 2 DM.

The acute effect of resistance training (RT) and aerobic training (AT) session was analyzed in a group of 10 volunteers of both genders aged 45-70 years, all with type 2 DM. It was investigated the behavior of BP over 24 hours, then the

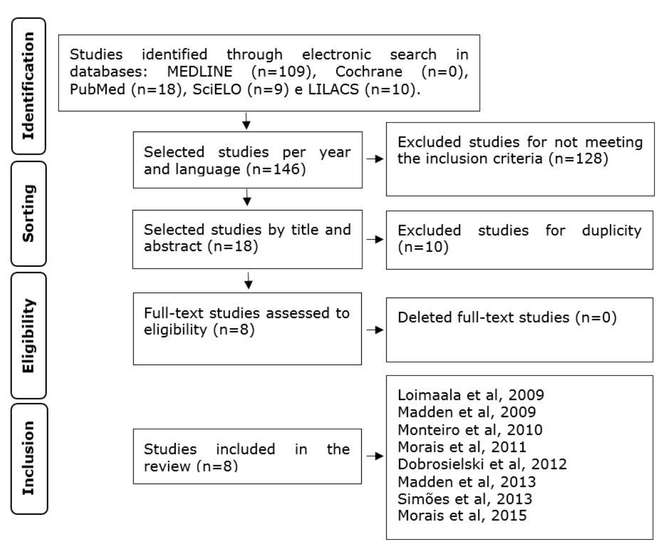

Figure 1. Search and selection of studies ofr literature review. n - number

Table 1. Summary of originals articles.

Authors and year	Sample of study	Analyzed variables	Methods	Results
LOIMAALA et al., 2009.	n= 50 ♂ $\bar{x}$ = 52,3 DM2.	PWV	Two randomized groups, with 24 months of intervention: - EG: AT by running or walking and RT for major muscle groups through machines and weights, 2 times per week, during 30' in different days; - CG: standard treatment for DM.	2 dropouts in each group; Non-significant trend towards slower progression of PWV in EG group during intervention.
MADDEN et al., 2009.	n = 36 $\bar{x}$ = 71,4 ♂ = 19; ♀ = 17 DM2; Sedentary lifestyle; Hypertension; Hypercholesterolemia.	PWV radial PWV femoral	Two intervention groups randomly, 3 times per week and during 3 months each: - AT: 60' of exercises on treadmill and cycle ergometer; - NA: Non aerobic exercises of core (exercise ball) And strength training (dumbbells).	2 dropouts in each group; ↓ of AS radial (P = 0,005) and femoral (P = 0,015) in AT; ↓ of ~20,7 ± 6,3% in PWV radial and of 13,9 ± 6,7% in PWV femoral in AT; ↑ of 8,5 ± 6,6% in PWV radial and of 4,4 ± 3,3% in PWV femoral in NA.
MONTEIRO et al., 2010.	n = 22 ♀ $\bar{x}$ = 61 DM2; Sedentary lifestyle.	SBP DBP	Two randomized groups, with 13 weeks of intervention: - AT: 50' on treadmill, 3 times per week; - CG: 2h of educational guidelines, 1 time per week.	↓ of SBP and DBP in two groups; ↓ significant of DBP basal and final in AT (p<0,01), where DBP final had a reduction of 27,0%.
MORAIS et al., 2011.	n = 10 $\bar{x}$ = 55,8 ♂ = 3; ♀ = 7 Ages: 45-70 years DM2; Sedentary lifestyle.	SBP DBP MAP	Subjects were assessed for 24 hours after a single session: - AT: 20' cycling; - RT: 3 laps in a circuit of 6 exercises with 8 repetitions; - CG: No exercise.	RT was more effective in promoting protective effects of SBP, DBP and MAP (p<0,05); RT provided more benefits for BP control (p<0,05).
DOBROSIELSKI et al., 2012.	n = 140 ♂ ♀ $\bar{x}$ = 52,5 Ages: 40-65 years DM2; BP not-good; untreated; Treated hypertension.	BP AS	Two randomized groups, 3 times per week, during 26 weeks: - RT: Two sets of 7 exercises, with 10-15 repetitions per exercise in 50% of 1RM; - AT: 45' on treadmill, cycle ergometer or stairs tepper; - CG: Exercise guide, dietary guidelines and PB monitoring.	22 dropouts and 2 exclusions; 114 individuals completed the 6 month intervention; Ø significant reductions in PWV, SBP and DBP at the end of the 6 months in both groups.
MADDEN et al., 2013.	n = 52 $\bar{x}$ = 69,3 ♂ = 30; ♀ = 22 DM2; Hypertension; Hypercholesterolemia.	PWV radial and femoral SBP DBP MAP	Two randomized groups, 3 sessions per week and during 6 months each: - AT: 60' on treadmill and e cycle ergometer; - NA: not-strenuous core exercises (exercise ball) and non-strenuous strength training (Very light weights, without load increase); Each subject was submitted to three evaluation sessions: T0, T3 and T6.	There were significant differences in PWV radial and femoral between groups of AT and NA; After 3 months of training: ↓PWV radial and femoral in AT group; ↓ of ~21,7 ± 6,7% in PWV radial and of 22,8 ± 7,2% in PWV femoral in AT; ↑ of 0,2 ± 4,2% in PWV radial and of 0,7 ± 7,3% in PWV femoral in NA. None of the reductions observed in AT were maintained throughout the course of the intervention; Ø significant reduction in SBP and DBP after 6 months.

n – sample number; ♂ – male; $\bar{x}$ – mean; DM2 – type 2 Diabetes mellitus; PWV – pulse wave velocity; EG – Exercise group; AT – aerobic training; RT – resistance training; CG – control group; DM – Diabetes mellitus; ♀ – female; NA – non-aerobic training; ↓ – reduction; AS – arterial stiffness; ~ – approximation; ↑ – increase; SBP – systolic blood pressure; DBP – diastolic blood pressure; MAP – mean arterial pressure; BP – blood pressure; 1RM – one repetition maximum; Ø – none; T0 – baseline training session; T3 – one evaluation after 3 months of training ; T6 – one evaluation after 6 months of training; LT – Lactate threshold; CS – control session; MAX – maximal exercise; MOD – moderate exercise.

Table 1. Continued...

Authors and year	Sample of study	Analyzed variables	Methods	Results
SIMÕES et al., 2013.	n = 20 ♂ =17; ♀ = 3 Ages: 40-60 years DM2; Without DM2; Sedentary lifestyle; Hypertension.	SBP DBP MAP	Subjects were evaluated through two sessions on different days: - Moderate AT: 20' of exercise on cycle ergometer with constant load (90% of the LT); - CS: 20' resting in sitting position. The collection of variables also occurred during the 20' pre-session and 45' post-session period.	↓ Significant of SBP post-exercise in both groups; The group without DM2 had lower values of SBP in resting and post-exercise; ↓ of MAP post-exercise only in group without DM2; ↓ of DBP post-exercise only in group with DM2.
MORAIS et al., 2015.	n = 10 $\bar{x}$ = 55,8 ♂ = 3; ♀ = 7 Ages: 45-70 years DM2; Sedentary lifestyle; Pre-Hypertension.	SBP DBP MAP	Subjects were evaluated during 24 hours after three sessions on different days: - MAX: Cardiopulmonary exercise testing; - MOD: 20' of exercise on a stationary bicycle with constant load (90% of LT); - CS: 20' resting in sitting position.	MAX promoted: ↓ in SBP, DBP and MAP over 24 hours when compared to the day of CS; ↓ significant in variation of the pressure during sleep in relation to the CS; ↓ significant of SBP compared to the MOD session. Ø significant differences in SBP, DBP and MAP after MOD compared to MAX and CS sessions during 24h.

n – sample number; ♂ – male; $\bar{x}$ – mean; DM2 – type 2 Diabetes mellitus; PWV – pulse wave velocity; EG – Exercise group; AT – aerobic training; RT – resistance training; CG – control group; DM – Diabetes mellitus; ♀ – female; NA – non-aerobic training; ↓ – reduction; AS – arterial stiffness; ~ – approximation; ↑ – increase; SBP – systolic blood pressure; DBP – diastolic blood pressure; MAP – mean arterial pressure; BP – blood pressure; 1RM – one repetition maximum; Ø – none; T0 – baseline training session; T3 – one evaluation after 3 months of training ; T6 – one evaluation after 6 months of training; LT – Lactate threshold; CS – control session; MAX – maximal exercise; MOD – moderate exercise.

workout; and compared to the control group (CG). The RT was performed with intensity equivalent to 70% of one repetition maximum (1RM); AT was 20 minutes long and was held in cycle ergometer for lower limbs; and CG did not perform any type of exercise. After two hours there was a reduction in systolic blood pressure (SBP) compared to CG; and the TR was more effective in promoting protective effects of SBP, diastolic blood pressure (DBP) and mean arterial pressure (MAP) after 24 hours when compared to the AT.[13]

Acute adjustments of different AT intensities on BP were also observed in a group of 10 individuals with type 2 DM, of both genders and aged 45-70 years. The volunteers participated in three experimental sessions supervised, characterized by maximal exercise (MAX), moderate exercise (MOD) and control session (CS), and had the BP monitored for 24 hours after each session. MAX is a cardiopulmonary exercise test; the MOD was characterized by 20 minutes exercise on a stationary bicycle; and CS for 20 minutes of rest in the sitting position. The study results showed that the MAX promoted reductions in SBP, DBP, and MAP over 24 hours when compared to CS; as well as a significant reduction in the variation of pressure during sleep compared to the CS session, and also in SBP compared to MOD session.[14]

Acute behavior of the BP, after a moderate AT session and a CS was also examined in 20 subjects of both genders and aged 40-60 years. Participants were also divided equally into two groups, one composed of individuals diagnosed with type 2 DM and another for individuals without type 2 DM. The BP measurement was performed before the moderate AT sessions and CS every 5 minutes within 20 minutes; during the sessions on 10 and 20 minutes; as well as after the sessions every 15 minutes within 45 minutes. Moderate AT was performed on a cycle ergometer for 20 minutes at a constant load corresponding to 90% of the lactate threshold; in CS the participants remained at rest for a period of 20 minutes. Both groups had significant reductions in SBP in post-exercise compared to resting values; the group without type 2 DM had lower SBP at rest and after moderate AT compared to the group with type 2 DM; only the group without type 2 DM had reduced post-exercise MAP; on the other hand, only the group with type 2 DM had decreased DBP after moderate AT.[15]

Another study evaluated the chronic effect of AT in BP for 13 weeks in 22 elderly women with type 2 DM and aged 60-64 years. The AT group walked three times a week with intensity of 60, 70 and 80% of maximum heart rate (MHR) for 50 minutes; the CG received educational guidelines during 2 hours, once a week. Although both groups have decreased SBP and DBP, no significant differences in SBP between the AT and CG; on the other hand, between the initial and final DBP in the AT group it was obtained a significant difference, which achieved a 27% reduction in final DBP.[16]

Chronic adaptations of AT and not-aerobic (NA) on BP were also evaluated over six months in 52 individuals of both genders and aged over 65. The AT was performed on a cycle ergometer three times a week, for 60 minutes; NA also contained three sessions per week and it was characterized by non-strenuous activities with minimal aerobic component, including exercises with balls and lightweight. At the end of six months, it was observed that the AT did not interfere with arterial stiffness (AS) in the patients with type 2 diabetes, because there were no significant differences in SBP and DBP between the two groups.[17]

The same result, no changes in DBP and SBP, was found in another study that evaluated the chronic effects of AT and RT in 114 individuals of both genders, aged 40-65 years, for 26 weeks. The RT consisted in seven exercises with two sets of 10-15 repetitions and intensity of 50% of 1RM, where the weight was increased when the participant could perform 15 repetitions of an exercise with less difficulty. The AT lasted for 45 minutes and participants could choose the treadmill, stationary bike or stair stepper for workout. The CG received a guide to physical activity, dietary guidelines and monitoring of PA. The exercises were performed at a frequency of three times a week.[18]

Different the studies related to the BP, it was found four studies that investigated the effect of exercise on AS in patients with type 2 DM.[17,18,19,20] However, as seen in studies that examined the exercise effect on BP, the following reported results refer to type 2 diabetic populations studied in articles that attended the inclusion criteria.

The chronic effect of AT and NA was analyzed in the study lasting six months, in 52 elderlies of both genders and with average age of 69.3 years. The AT consisted of moderate to vigorously intensity exercise (60-75% of heart rate reserve) on a treadmill and cycle ergometer, three times a week during 60 minutes each. In group NA activities, were performed not strenuous exercise core with ball and strength exercises with very light weights, with no load change also for three sessions per week. This study found significant differences in the results obtained between the groups after three months of training, with reduction of the Pulse Wave Velocity (PWV) radial and femoral in the AT group and increased in NA group. However, these results were not maintained after six months of training, demonstrated by none difference between the two PWV groups.[17]

Similar results were observed after three months of AT and NA in 36 elderlies of both genders with an average age of 71.4 years. In the AT group, it was performed moderate to vigorously intensity exercise (60-75% of heart rate) on a treadmill and cycle ergometer, keeping the same frequency (three times a week) and duration (60 minutes) from the previous study. In the NA group, it was also carried out core training with ball and strength exercises with dumbbells, keeping the frequency of three sessions per week. A total of 34 subjects completed the intervention and at the end of three months, it was found a reduction of radial and femoral PWV in subjects who underwent the AT, differently of those in the NA group, which evolved with increased PWV in both arteries.[19]

Another study randomized 140 subjects of both genders and type 2 DM patients to physical training and control groups. The exercise sessions were conducted with a frequency of three times a week and included aerobic and resistance components. Only 114 participants with an average age of 56.4 years completed the six-month intervention, and PWV was assessed only in 94 of them. The RT consisted by seven exercises with two sets of 10-15 repetitions and intensity of 50% of 1RM, with progressive loads, modified when the participant could complete 15 repetitions referring less difficulty. The AT was performed on a treadmill, stationary bike or stair stepper for 45 minutes. The control group received a guide to physical activity, dietary guidelines and monitoring of BP. In conclusion, there are none significant reductions in aortic PWV after six months of intervention comparing the groups.[18]

Similarly, it was not observed positive results in AS in an intervention during two year in men with type 2 DM. A total of 50 participants with an average age of 52.3 years was distributed, randomly, in control and exercise groups, respectively differentiated by standard DM treatment and aerobic and muscle strengthening exercises. The AT was to walk or run twice a week at a heart rate (HR) corresponding to 65-75% of VO_{2max} revised every six months by a strenuous physical test. The RT was also performed twice a week, consisting of eight exercises for major muscle groups, with three to four sets of 10-12 repetitions and progressive intensity, 60-80% of 1RM. The intervention by the RT included 12 different training programs that have been modified every two months; each session of AT and TR had a minimum duration of 30 minutes. During the study, there was loss of one participant in each group and was observed a slower convergence to progression of AS in the exercise group (AT and RT), however, it was not significant, leading to the conclusion that this intervention method can not improve arterial elasticity.[20]

DISCUSSION

The findings showed that after 24 hours, the acute effect of high intensity RT (total of 144 repetitions per session) was effective in promoting protective effects on the SBP, DBP and MAP, as compared to AT. The physiological mechanisms related to the reduction in values BP are associated with muscle vasodilation after resistance exercise, because the metabolites accumulation in the muscles causes a compensatory vasodilatation, which reduces the afterload and peripheral vascular resistance.[13,22]

The high intensity RT (70% of 1RM), involving large muscle groups and a high volume of exercise (total of 144 repetitions), recruit more motor units and determines a greater activation of the endothelium-dependent vasodilation, leading to reduced resistance peripheral vascular and, hence, the BP.[13,22,23,24]

The reduction in BP after RT, the analysis of hypertensive elderly, may have been caused by reduced cardiac output, which in turn is mediated by the decrease in ejection volume, possibly caused by the decrease of the venous return; and by other mechanisms still unknown.[25]

Thus, it is possible to observe that still there are controversial findings that identify the effect of RT on BP, requiring further research to clarify the mechanisms involved in the adaptation of the BP. Anyway, this BP reduction obtained through the RT, may decrease the risk of acute myocardial infarction and coronary heart disease, may characterize it as a effective non-drug therapy not only for the prevention but also for the treatment and control of arterial hypertension.[25,26]

On the other hand, the findings of 24-hour ambulatory BP monitoring suggest that a single session of aerobic exercise can promote reductions in BP in individuals with type 2 DM, especially during sleep, and which exercise intensity plays an important role in the size of the reduction, since it was more marked after the MAX session.[14] Thus, it is possible that the mechanisms involved in these adaptations are due to the accumulation of metabolites and heat dissipation induced by exercise, leading to muscle vasodilation and hence to a decrease in peripheral vascular resistance and decrease in BP, should happen more markedly in exercises with higher intensities.[27]

It is also important to note that individuals with type 2 DM may have endothelial dysfunction and reduced vasodilator response, factors that suggest the occurrence of failure in the reduction mechanism of peripheral vascular resistance in this population, where this limitation would be more evident through less vigorous exercises.[14]

It is important to note that the greatest reduction in SBP, during sleep observed in post MAX period, is very important for individuals with type 2 diabetes because it is believed that a low nocturnal BP (<10%) associated to hyperglycemia have significant correlation with the increased risk of cardiovascular events, suggesting once again that exercise at higher intensities are most promising for hypertensive diabetic patients.[14,28]

Still in this context, it was found that a single AT moderate session is able to reduce SBP during the post-exercise recovery in subjects with and without type 2 DM, in which, however, promotes a stronger hypotensive effect in non-diabetic subjects. The mechanisms included in these responses may be related to greater capacity of releasing of vasodilator substances belonging to the kallikrein-kinin system identified in non-type 2 diabetics individuals, which leads to higher post-exercise hypotension. In contrast, endothelial dysfunction caused by the diabetic condition would be responsible for reducing the activity of this system, linked to a possible degradation of bradykinin by angiotensin-converting enzyme, which impose a lower responsiveness to exercise on this population.[15,29]

However, it is believed that type 2 DM carriers also benefit from the effects of exercise, as was observed significant reductions in SBP and DBP in this group, possibly resulting from the improved activity of the kallikrein-kinin system induced by moderate AT.[15]

Similarly, after 13 weeks of AT in a population of 11 elderly women, it was observed a significant reduction of the values of basal and final in the DBP, equivalent to 27%, associated with a slight decrease of SBP.[16] The mechanisms involved in these adaptations may be related to muscle contractions rhythmical promoted by the AT, which increased the sympathetic nerve activity, generating an elevation of cardiac chronotropism and inotropic and a reduction in peripheral vascular resistance, due to vasodilation of the active muscles. Thus, the AT is able to promote a more significant decrease in DBP compared to SBP. Importantly, the greater reduction in DBP in hypertensive diabetic patients are able to mitigate the occurrence of cardiovascular events, coronary artery disease, stroke and congestive heart failure.[30,31,32]

On the other hand, the difficulty in BP reduction after 6 months of RT and AT[17,18] can be justified by the association of metabolic changes of diabetes, which in turn, impairs vascular function. The impairment of endothelium-dependent activity reduces nitric oxide levels and, thus, promotes vasoconstriction and may contribute to structural remodeling and AS, leading to increase of BP.[21]

Another limitation found is that, in the population studied, high blood pressure was treated with medication, leading to the fact that the exercise association with antihypertensive medication does not allow the isolated assessment of the effects of physical exercise. In this context, most of the samples used of antihypertensive medications and the authors did not interrupt the prescription, suggesting that this factor may also have interfered in the non-significant reduction in SBP and DBP. However, it is necessary the combination of drug therapy to exercise as an adjunct treatment for high blood pressure in type 2 diabetic patients.[18,33]

It should be clarified that the AT concomitantly with TR are indicated for the prevention and treatment of arterial hypertension, because they generate reductions in BP; improve the health and life quality; promote the control of blood glucose and triglycerides and increase HDL cholesterol; reduce obesity, sarcopenia and osteoporosis present in the physiological aging process and, hence, the occurrence of fractures. Additively, it improves the quality of sleep, cognitive function and short-term memory; decrease the degree of depression and reduce or delay the onset of dementia; reduce the risk of colon cancer, breast, prostate and rectum; among other benefits related to cardiovascular function, musculoskeletal and metabolic.[30,34,35]

With respect to RA, it is known that it increases gradually with advancing age and type 2 DM promotes a worsening of this natural aging process. Among the possible pathophysiological mechanisms that promote changes in vascular function in diabetic patients, they are the increased insulin resistance and the resulting hyperinsulinemia, which has been associated with increased AS. In turn, the non-enzymatic glycation, process linked to hyperglycemia, may also directly affect the structure and function of large arteries, it increases the cross-linked collagen in the arterial wall, with consequent reduction of its distensibility. In addition to these factors, it also suggest the involvement of the autonomic nervous system in mediating AS changes present in diabetics patients.[10,16]

Considering the articles selected for this review, two had reduced AS after three months of AT, however, in one of them the result was not maintained after six months of intervention. Likewise, it was not observed the improvement of AS after six months and two years of AT and RT when compared to CG.[17,18,19,20] Analyzing the outcomes shown after three months of AT, it is believed that this type of exercise is capable of promoting higher responses for the nonenzymatic glycation, resulting in stretching and breakage of collagen cross-links. This response associated with improved sympathetic tonus and increase nitric oxide-induced vasodilation activity, which are also achieved through the AT, may explain the reductions in AS obtained in short term.[17,19]

On the other hand, the non-permanence of this response after six months of the intervention[17], suggest that the changes from the arterial stiffening presents components with progressive and irreversible characteristics and may promote a resistance to AT over longer periods. This may also explain not improved arterial elasticity when it confronted the responses obtained between exercise and control groups after six months and two years of the intervention.[18,20]

Considering that those which associated RT programs, another studies show a strong association of this high intensity exercise modality with increasing AS, different of those which used moderate and obtained disparate outcomes. Distinct evidence confirms these findings and shows that the RT reduces arterial compliance in different populations, but that the use of lower intensities do not promote these alterations.[37,38]

It is important to note that these findings should not confirm a contraindication to RT, since this type of exercise promotes beneficial adaptations to the patient with type 2 diabetes here already mentioned.[34] In this context, the combination of RT and AT is characterized by an effective alternative, since the aerobic component seems to act as a neutralizer for the increase of AS and may even induce greater vascular distensibility.[38]

However, it is important to emphasize that the constituent population of the studies selected for this review is characterized by older individuals, with type 2 DM and have other associated morbidities, a fact that reflects major cardiovascular risk which can not possibly be reversed only through the physical exercise.[18]

It is also necessary to point out the difficulty in systematizing the exercise protocols used in the studies, since the heterogeneity related to the type of exercise; number of sets and repetitions; time; intensity and volume of exercise; muscle groups involved and duration of action, may affect the quality of the displayed outcomes and consequently to difficult the proper exercise prescription for individuals with type 2 diabetes.

CONCLUSION

The results suggest that physical exercise may be indicated as a promising non-pharmacological strategy for pressure control in type 2 DM patients. Regarding arterial stiffness, it is assumed that the structural alterations involved in the disease process are irreversible, and may not be modified even after long periods of intervention. However, further studies are necessary to fully understand the mechanisms involved in reducing arterial pressure and stiffness in type 2 diabetic subjects. In this sense, it is essential to systematize physical exercise programs, in order to elucidate their effects on the pressure and arterial stiffness in patients with type 2 DM.

AUTHOR'S CONTRIBUTION

MRAM, PTRB: Search for articles and text writing. MLM, RMVS: Orientation, revision of text and discussion of work.

CONFLICTS OF INTEREST

The author(s) declare that they have no competing interests.

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