Original Article

Effect of a single exercise session on blood glucose and blood pressure in elderly

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Abstract

The relative risk to developing chronic diseases such as cardiovascular disease, type II diabetes mellitus, obesity and certain types of cancer, increases with age. Thus, aging associated with a poorly active lifestyle is considered one of the primary risk factors for the development and progression of most chronic degenerative diseases, while regular exercise has substantially changed this scenario. Exercise acts favorably on blood glucose and blood pressure, but few studies have been concerned to compare the effect of different exercise modalities on these physiological variables. Therefore, the aim of the present study was to analyze the acute effect of exercise on post-exercise hypotension (PEH) and blood glucose in the elderly. Thirty elderly (67 ± 5.2 years) of both genders were selected and separated according to the exercise modality practiced: AE, aquatic exercise (N = 6); RT, resistance training (N = 6); F, functional/ weight bearing training (N = 6); P, Pilates (N = 6); C, sedentary/control (N = 6). Blood pressure and blood glucose were recorded 15 minutes before the beginning and 30 minutes after the end of the training session. Thus, it was found that the RT (systolic PEH and blood glucose) and the AE (diastolic PEH) were able to promote the most significant reductions when compared to other modalities, thus being preferentially recommended for the elderly population with characteristics close to the sample used in this research.

Keywords: Pilates, resistance training, weight bearing, aquatic exercise.

Introduction

The relative risk of developing several chronic diseases, such as cardiovascular disease, type II diabetes mellitus, obesity, and certain types of cancer, increases with age (Lakatta and Levy, 2003; Singh, 2004). Thus, aging is related to the development and progression of most chronic-degenerative diseases, but regular physical exercise can substantially and favourably change this situation (Chodzko-Zajko et al., 2009).

Hypertension is one of the most common health disorders that is associated with an increased incidence of mortality. It is characterized by elevated values, whether systolic (SBP) or diastolic blood pressure (DBP), equal to or greater than 140 and 90 millimetres of mercury (mmHg), respectively (ACSM, 2004). According to Silva Filho et al. (2014), 12.8% of the population dies because of systemic arterial hypertension. Lifestyle modification is associated with a reduction in resting BP and is considered a low-cost intervention that has no side effects. This modification involves physical activity as a fundamental cornerstone (Chobanian et al., 2003).

One of the greatest benefits of physical exercise is a reduction in BP after the exercise, which is known as post-exercise hypotension (PEH). Several studies have demonstrated the effect of physical exercise on PEH, such as the study by Brandão Rondon et al. (2002) that demonstrated a PEH that lasted 22 h after performing an activity with a predominance of aerobic metabolism in hypertensive elderly.

Another chronic disease common to the elderly is diabetes mellitus (DM). The term DM is used to describe a metabolic disorder of multifactorial origin. It is characterized by chronic hyperglycemia that is associated with a disturbance in the metabolism of carbohydrates, fats, and proteins. It results in a deficiency in insulin secretion and production or both. The effects of DM include characteristic symptoms, such as excessive thirst, polyuria, weight loss and blurred vision. In more severe cases, it may result in ketoacidosis or a non-ketotic hyperosmolar state and lead to a stupor, and with the absence of effective treatment, it leads to death (WHO, 1999). Type 2 diabetes mellitus (DM2) is mostly related to aging. Considered a metabolic disease, it is also characterized by hyperglycemia that usually results from complications from insulin action or both. Chronic hyperglycemia of DM2 is associated with prolonged damage, dysfunction, and failure of different systems and/or tissues, especially the eyes, kidneys, nerves, heart, and blood vessels (ADA, 2010).

Many studies have demonstrated the effect of exercise on the reduction and consequent control of blood glucose in diabetic individuals. However, most of these studies used aerobic exercise (Lumb, 2014). Weight-bearing exercises are a very practical and effective option to keep the body working because they do not require

sophisticated appliances and increase functional capabilities, muscular flexibility, lower limb strength, and quality of life in the elderly (Machado et al., 2019).

Nevertheless, currently, many elderly chose or even complement their exercise routine with resistance exercises. Resistance training is an extremely safe systemic physical activity, and it has no contraindications if well oriented, in addition to being the fastest growing physical activity in the world in several practitioners settings. Resistance training provides benefits for all ages and clinical conditions. According to the maximum range of motion allowed for each individual, it involves the performing of necessary movements to maintain or recover functional independence. As a result, improvements in muscle function are obtained, which stimulates an increase in bone mass and decreases cardiac overload (Marega, 2012). Some studies have shown the effect of this type of exercise on blood glucose (Westcote, 2012; Kirwan et al., 2017; Monroe et al., 2020) and blood pressure (Sousa et al., 2017; Nascimento et al., 2018).

Another activity sought and practiced by the elderly is aquatic exercise as an effective exercise for preventing postprandial hyperglycemia (Kurobe et al., 2018) and improving lower limb strength, functional capabilities, muscular flexibility and quality of life (Machado et al., 2019).

Regarding prescribed exercise, the planning of the overload, that is, the intensity and volume of training, is a fundamental issue (Richens and Cleather, 2014).

Regarding the effect of exercise on PEH and blood glucose, there is considerable controversy according to prior studies. This is likely due to the use of different training protocols that included different amounts and intensities of exercise.

Therefore, the aim of this study was to analyse the effect of different forms of physical exercise on post-exercise hypotension (PEH) and blood glucose in the elderly.

Materials & Methods

Scenery

This study followed the rules of research on humans in accordance with Resolution 466/12 of the Ministry of Health and was authorized by the educational institution in question. It was approved by the Ethics Committee of the Faculty of Medical and Health Sciences of PUCSP (87868118.0.0000.5373). The study included as its research field the Physical Conditioning Room of the Sorocaba's YMCA Physical Education Faculty (FEFISO).

Participants

This study assessed 30 elderly (67 ± 5.2 years old) of both sexes who were members of the Sorocaba's YMCA and regular users of the systematic physical exercises offered by the aforementioned establishment. The sample was divided into five groups as follows: six resistance training practitioners (RT), six functional training practitioners (F), six aquatic exercise practitioners (AE), six Pilates practitioners (P) and six who were sedentary (C). Regarding the experimental groups, all had six months or more of practice in the activities mentioned above with a weekly frequency of three days during the last six months. For the control group, only sedentary elderly people were selected. Smokers and those taking anti-inflammatory medication were excluded from this study.

Exercise Protocol

Aquatic exercise classes consisted of an initial 10 to 15 min of general warm-up, followed by 25 to 35 min of specific activity for the upper and lower limbs. The final 5 to 10 min were reserved for stretching and relaxation exercises. The functional training included between 5 and 10 min of warm-up using low-intensity cyclical and/or acyclic activities. The main part of the training consisted of 30 to 35 min of performing exercises using their own body weight. During this stage, the elderly women performed jumps, burpees, squats, stationary runs, jumping jacks, push-ups, abdominal exercises, among others. The stimuli lasted between 1 and 1.5 min, which were separated by 1 min of passive recovery. The final 5 to 10 min of the lesson was reserved for stretching and relaxation exercises.

Regarding resistance training, it consisted of seven exercises: one for each body region with four series of ten repetitions. The main exercises used and their sequence included: seated chest press, seated row machine, lateral raise, leg press, leg curl, standing calf raise machine, and abdominal machine. Recovery between sets lasted 1.5 to 2 min, and the total session duration was approximately 50 to 60 min.

Pilates classes consisted of an initial 10 min of general warm-up, followed by 40 min of specific activity for the upper and lower limbs (stretching, strengthening, and posture exercises). The final 5 to 10 min were reserved for relaxation exercises.

All groups had the same training pattern, which consisted of three weekly sessions. The exercise intensity was controlled using the CR-10 scale (Borg, 1998). During the exercise session, the individuals were instructed to maintain the intensity between the values of 4 (moderate) and 5 (heavy) on the scale mentioned above.

Measurements

Blood glucose was recorded 15 min before the beginning of the exercise session and 30 min after the end of it. The measurement of resting blood pressure followed the protocol recommended by Frese et al. (2011). For the measurements, an HBP-1100-OMRON® Automatic Arm Pressure Device and an Accutrend Plus Roche® blood glucose tester were used.

Statistical Analysis

The results were analysed using the GraphPad Prism 8.0 program using the mean, standard deviation, and Dunn's test for nonparametric data to identify the significant differences ($p < 0.05$), which, when present, were confirmed by Tukey's post-test.

Results

The values for BP and pre-exercise blood glucose (at rest) are shown in Table 1.

Table 1. Pre-exercise blood pressures and blood glucose levels (at rest)

	SBP (mmHg)	DBP (mmHg)	Glucose (mg/dL)
Aquatic Exercise	136,7 $\pm$ 4,0	88,3 $\pm$ 4,0	110,2 $\pm$ 15,6
Resistance Training	135,8 $\pm$ 10,2	82,5 $\pm$ 7,5	121,3 $\pm$ 12,4
Functional Training	131,7 $\pm$ 14,7	83,3 $\pm$ 8,1	101,8 $\pm$ 13,2
Pilates	135,1 $\pm$ 5,4	81,6 $\pm$ 7,5	122,7 $\pm$ 4,0
Control	141,1 $\pm$ 8,3	89,4 $\pm$ 8,3	123,9 $\pm$ 17,6

Comments: SBP = systolic blood pressure; DBP = Diastolic Blood Pressure. Values expressed as means and standard deviations.

We found that the main factor associated with PEH and a reduction in blood glucose was the regular practice of physical exercise. In addition, among the different types of exercises evaluated, RT had a greater effect on BP and blood glucose. As shown in Figure 1, with regard to PAS, the performance of any of the forms of physical exercise resulted in a significantly higher PEH ($p < 0.05$) than the control group.

Figure 1. Differences in SBP values before and after exercise for the groups: AE, aquatic exercise; RT, resistance training; F, functional training; P, Pilates; and C, control. The values are presented as the means $\pm$ standard errors of the means. * Statistical difference ($p < 0.05$) between the groups that practiced physical exercise and the control group (C). # Statistical difference ($p < 0.05$) between the RT group and the F and P groups. Another result was the difference between the RT group and the F and P groups. The resistance training practitioners demonstrated greater HPE compared to those who performed functional training and Pilates. Regarding DBP, although we observed the tendency of physical exercise to cause greater PEH, there was no significant difference ($p < 0.05$) compared to C (Figure 2).

Figure 2. Differences in DBP values before and after exercise for the groups: AE, aquatic exercise; RT, resistance training; F, functional training; P, Pilates' and C, controls. The values are presented as the means $\pm$ standard errors of the means. * Statistical difference ($p < 0.05$) between aquatic exercise (AE) and the control (C).

In the study, we also verified the acute effect of physical exercise on blood glucose. As shown in Figure 3, an isolated exercise session was capable of causing a significant reduction in blood glucose, and among the groups that practiced physical exercise, the RT group stood out.

Figure 3. Differences in glycemic values before and after exercise for the groups: AE, aquatic exercise; RT, resistance training; F, functional training; P, Pilates; and C, control. The values are presented as mean $\pm$ standard errors of the means. * Statistical difference ($p < 0.05$) between the groups that practiced physical exercise and the control group (C). # Statistical difference ($p < 0.05$) between group RT and groups AE, F and P.

Discussion

The objective of this study was to verify the effect of different types of physical exercises on blood glucose and post-exercise hypotension.

According to MacDonald et al. (2016), hypertension is one of the most common medical disorders, which is associated with an increased incidence of mortality from any cause. Thus, after analysing 64 studies and 2344 individuals, MacDonald found that, according to his meta-analysis, resistance training is as effective as aerobic training on PEH. In another meta-analysis carried out by Cornelissen and Smart (2013), they compared aerobic and resistance training in terms of their influence on BP reduction. The authors concluded that individuals who performed resistance exercise that contained isometric actions during their training session achieved the greatest reduction in BP.

Therefore, although both resistance training and aerobic exercises have a significant effect on PEH, a study by Artero et al. (2011) demonstrated the strong correlation between muscle strength and the lower probability of death from any cause in hypertensive individuals. These results demonstrate the protective effect of muscle strength, especially in hypertensive individuals.

In our study, we found that the resistance training practitioners showed higher PEH compared to those who performed functional training and Pilates, and after measuring the hemodynamic behaviour of elderly women who performed the Pilates method, Bueno et al. (2019) also found modest HPE.

Regarding DBP, in our study, although we observed a tendency towards greater diastolic PEH between the groups who practiced physical exercise, we found a significant difference only between groups AE and C. However, Cunha et al. (2017) found no difference in the diastolic PEH 30 min after a 45-min session of aerobic activities in the water in elderly women. One probable explanation is the fact that the resting DBPs of the elderly analysed in our study were higher than those of the elderly in the aforementioned study (88.3 ± 4.0 vs. 66.4 ± 9.7 , respectively). Thus, as mentioned by Casonatto and Polito (2009), performing exercises with pressure values above the normal range appears to increase the PEH.

DM is a syndrome characterized by metabolic disorders that involve hyperglycemia owing to a deficiency in the secretion or action of insulin (Santos and Pinho, 2012). Chronic hyperglycemia can lead to the dysfunction and failure of several organs, such as the eyes, kidneys, nerves, heart and blood vessels, and it must be diagnosed and treated early so that these consequences are prevented. Proven non-pharmacological therapy has been suggested as the first line of defence against this condition because it has been shown to be very effective. In addition, there is a lower risk of side effects, which can considerably contribute to quality of life (Colberg et al., 2016). Many studies have demonstrated the effects of exercise on the reduction and control of blood glucose in diabetic individuals. However, most studies have used aerobic exercise as a tool (Colberg et al., 2013; Lumb, 2014).

Now, many elderly people choose to use or complement their exercise routine with resistance exercises. Resistance training is a systematic and extremely safe physical exercise with no contraindications if well oriented, in addition to being the fastest growing physical exercise in the world in terms of the number of practitioners (Marega, 2012). When comparing the effects of aerobic exercises with resistance exercise, Wróbel et al. (2018) did not notice significant differences in glycemic control.

After analysing 37 studies, Pan et al. (2018) concluded that both forms of exercise, aerobic and resistance, are effective for a reduction of blood glucose in diabetic individuals; however, their combined use exceeds their isolated performance.

In our study, among the groups that practiced physical exercise, the RT group was the best in terms of reduced blood glucose. One possible explanation was the difference between the protocols applied in the different studies. Our protocol consisted of seven exercises (one for each body region) performed in four sets of ten movements for each with 1.5 to 2 min of recovery between sets/exercises. Thus, the high volume of training (28 total sets) combined with the short recovery interval was found to be effective at reducing glycemic levels in the population evaluated in this study.

Conclusion

Control of both blood glucose and blood pressure is essential for maintaining health and quality of life. Hypertension is one of the most common medical disorders, and it is associated with an increased incidence of mortality from any cause. Another chronic disease common to the elderly is diabetes mellitus. Chronic hyperglycemia of diabetes is associated with prolonged damage, dysfunction, and failure of different organs, especially the eyes, kidneys, nerves, heart, and blood vessels.

In this study, acute physical exercise was able to significantly reduce blood glucose and SBP after exercise in elderly individuals, and among the different exercise modalities assessed here, RT produced the greatest reduction. Regarding the acute effect of exercise on DBP, we conclude that it has a tendency to reduce it; however, only the AE group showed a significant reduction compared to group C.

Thus, in this study, we analysed the acute effect of different types of physical exercises on the post-exercise glycemic and hypotensive response in the elderly, and the data showed that RT (systolic HPE and blood glucose) and AE (diastolic HPE) produced the most significant reductions when compared to other modalities; thus, these types of exercises are recommended for elderly populations with characteristics similar to the sample used in this study.

References

- American College of Sports Medicine. (2004). Position Stand. Exercise and hypertension. *Med Sci Sports Exerc*, 36, 533–553.
- American Diabetes Association. (2010). Diagnosis and Classification of Diabetes Mellitus. *Diabetes Care*, 33(1), S62–S69.
- Artero, E.G., Lee, D., Ruiz, J.R., Sui, X., Ortega, F.B., Church, T.S., Lavie, C.J., Castillo, M.J., Blair, S.N. (2011). A prospective study of muscular strength and all-cause mortality in men with hypertension. *J Am Coll Cardiol*, 57(18), 1831–1837.
- Borg, G. (1998). *Borg's perceived exertion and pain scales*. Champaign, IL: Human Kinetics.
- Brandão Rondon, M.U., Alves, M.J., Braga, A.M., Teixeira, O.T., Barreto, A.C., Krieger, E.M., Negrão, C.E. (2002). Postexercise blood pressure reduction in elderly hypertensive patients. *J. Am. Coll. Cardiol*, 39, 676–682.
- Bueno, J.C.A., Alves, R.C., Smoralek, A.C., Souza Junior, T.P. (2019). Comportamento hemodinâmico e perceptual em idosas submetidas a uma sessão de diferentes protocolos do método pilates®. *Rev Bras Prescr Fisiol Exerc*, 13(83), 481–492.
- Casonatto, J., Polito, M.D. (2009). Hipotensão pós-exercício aeróbio: uma revisão sistemática. *Rev Bras Med Esporte*, 15(2), 151–157.
- Chobanian, A.V., Bakris, G.L., Black, H.R., Cushman, W.C., Green, L.A., Izzo, J.L., Jones, D.W., Materson, B.J., Oparil, S., Wright, J.T., Roccella, E.J. (2003). National Heart, Lung, and Blood Institute Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure; National High Blood Pressure Education Program Coordinating Committee. The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. The JNC 7 Report. *Hypertens*, 42, 1206–1252.
- Chodzko-Zajko, W.J., Proctor, D.N., Fiatarone, M.A., Minson, C.T., Nigg, C.R., Salem, G.J., Skinner, J.S. (2009). American College of Sports Medicine position stand: Exercise and physical activity for older adults. *Med Sci Sports Exerc*, 41, 1510–153.
- Colberg, S.R., Hernandez, M.J., Shahzad, F. (2013). Blood glucose responses to type, intensity, duration, and timing of exercise. *Diabetes Care*, 36(10), e177.
- Colberg, S.R., Sigal, R.S., Yardley, J.E., Riddell, M.C., Dunstan, D.W., Dempsey, P.C., Horton, E.S., Castorino, K., Tate, D.F. (2016). Physical Activity/Exercise and Diabetes: A Position Statement of the American Diabetes Association. *Diabetes Care*, 39(11), 2065–2079.
- Cornelissen, V.A., Smart, N.A. (2013). Exercise training for blood pressure: a systematic review and meta-analysis. *J Am Heart Assoc*, 2(1), e004473.
- Cunha, R.M., Vilaça-Alves, J., Noleto, M.V., Silva, J.S., Costa, A.M., Silva, C.N.F., Póvoa, T.I.R., Lehnen, A.M. (2017). Acute blood pressure response in hypertensive elderly women immediately after water aerobics

- exercises: a crossover study. *Clin Experim Hypertension*, 10(23), 17-22.
- Frese, E.M., Fick, A., Sadowsky, H.S. (2011). Blood pressure measurement guidelines for physical therapists. *Cardiopul Phys Ther*, 22(2), 5-12.
- Kirwan, J. P., Sacks, J., Nieuwoudt, S. (2017). The essential role of exercise in the management of type 2 diabetes. *Cleve Clin J Med*, 84(7), S15-S21.
- Kurobe, K., Kousaka, A., Ogita, F., Matsumoto, N. (2018). Metabolic responses to exercise on land and in water following glucose ingestion. *Clin PhysiolFunct Imaging*, 38, 227-232.
- Lakatta, E.G., Levy, D. (2003). Arterial and cardiac aging: major share- holders in cardiovascular disease enterprises: Part I: Aging arteries: a “set up” for vascular disease. *Circulation*, 107, 139–146.
- Lumb, A. (2014). Diabetes and Exercise. *Clin Med*, 14(6), 673-676.
- Macdonald, H.V., Johnson, B.T., Huedo-Medina, T.B., Livingston, M.L.S., Forsyth, K.C., Kraemer, W.J., Farinatti, P., Pescatello, L.S. (2016). Dynamic resistance training as stand-alone antihypertensive lifestyle therapy: a meta-analysis. *J Am Heart Assoc*, 5(10), e003231.
- Machado, O. A. S., Lima, W. P., Souza, B. V., Gianolla, F., Killian, L. F., Machado, G. A. C., Gorjão, R. (2019). Comparison of functional capability, flexibility, strength and quality of life in aged women engaged in resistance exercise, weight-bearing training or hydro-gymnastics. *Journal of Sports Science*, 7, 106-114.
- Marega, M. (2012). *Manual de atividades físicas para prevenção de doenças*. Rio de Janeiro: Elsevier.
- Monroe, J. C., Naugle, K. M., Naugle, K. E. (2020). Effect of acute bouts of volume-matched high-intensity resistance training protocols on blood glucose levels. *J Strength Cond Res*, 34(2), 445-450.
- Nascimento, D. C., Silva, C. R., Valduga, R., Saraiva, B., Sousa Neto, I. V., Vieira, A., Funghetto, A. S., Silva, A. O., Oliveira, S. C., Pereira, G. B., Willardson, J. M., Prestes, J. (2018). Blood pressure response to resistance training in hypertensive and normotensive older women. *Clin Interv Aging*, 13, 541-553.
- Pan, B., Ge, L., Xun, Y., Chen, Y., Gao, C., Han, X., Zuo, L., Shan, H., Yang, K., Ding, G., Tian, J. (2018). Exercise training modalities in patients with type 2 diabetes mellitus: a systematic review and network meta-analysis. *Int J Behav Nutr Phys Act*, 15(1), 72.
- Richens, B., Cleather, D.J. (2014). The relationship between the number of repetitions performed at given intensities is different in endurance and strength trained athletes. *Biol Sport*, 31(2), 157-161.
- Santos, P.A., Pinho, C.P.S. (2012). Diabetes mellitus em pacientes coronariopatas: prevalência e fatores de risco cardiovascular associado. *Rev Bras Clin Med*, 10(6), 469-75.
- Silva Filho, A.C., Castro Filha, J.L., Costa, H.A., Sá, E.S., Dias, C.J.M., Navarro, F. (2014). Mulheres apresentam maior pressão arterial após os 50 anos etários, quando comparadas às mais jovens. *Brasília Med*, 51(2), 97-102.
- Singh, M. (2004). Exercise and aging. *Clin Geriatr Med*, 20, 201–221.
- Sousa, E. C., Abrahin, O., Ferreira, A. L. L., Rodrigues, R. P., Alves, E. A. C., Vieira, R. P. (2017). Resistance training alone reduces systolic and diastolic blood pressure in prehypertensive and hypertensive individuals: meta-analysis. *Hypertens Res*, 40(11), 927-931.
- World Health Organization. (1999). *Definition, Diagnosis and Classification of Diabetes mellitus and its Complications. Part I: Diagnosis and Classification of Diabetes Mellitus (Department of Noncommunicable Disease Surveillance. Geneva)*.
- Westcott, W. L. (2012). Resistance training is medicine: effects of strength training on health. *Curr Sports Med Rep*, 11(4), 209-216.
- Wróbel, M., Rokicka, D., Czuba, M., Golas, A., Pyka, L., Greif, M., Szyborska-Kajane, A., Strojek, K., Gasior, M. (2018). Aerobic as well as resistance exercises are good for patients with type 1 diabetes. *Diabetes Res Clin Pract*, 144, 93-101.