

Blood Pressure and Hemodynamic Adaptations after a Training Program in Young Individuals with Down Syndrome

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Abstract

Background: Cardiovascular diseases affect people worldwide. Individuals with Down Syndrome (DS) have an up to sixteen-time greater risk of mortality from cardiovascular diseases.

Objective: To evaluate the effects of aerobic and resistance exercises on blood pressure and hemodynamic variables of young individuals with DS.

Methods: A total of 29 young individuals with DS participated in the study. They were divided into two groups: aerobic training (AT) (n = 14), and resistance training (TR) (n = 15). Their mean age was 15.7 ± 2.82 years. The training program lasted 12 weeks, and had a frequency of three times a week for AT and twice a week for TR. AT was performed in treadmill/ bicycle ergometer, at an intensity between 50%-70% of the HR reserve. TR comprised nine exercises with three sets of 12 repetition-maximum. Systolic blood pressure (SBP), diastolic blood pressure (DBP), mean blood pressure (MBP) and hemodynamic variables were assessed beat-to-beat using the Finometer device before/after the training program. Descriptive analysis, the Shapiro-Wilk test to check the normality of data, and the two-way ANOVA for repeated measures were used to compare pre- and post-training variables. The Pearson's correlation coefficient was calculated to correlate hemodynamic variables. The SPSS version 18.0 was used with the significance level set at $p < 0.05$.

Results: After twelve weeks of aerobic and/or resistance training, significant reductions in variables SBP, DBP and MBP were observed.

Conclusion: This study suggests a chronic hypotensive effect of moderate aerobic and resistance exercises on young individuals with DS. (Arq Bras Cardiol. 2014; [online].ahead print, PP.0-0)

Keywords: Arterial Pressure / physiology; Hemodynamic / physiology; Heart Defects / congenital; Down Syndrome; Adolescent; Resistance Training.

Introduction

Cardiovascular disease is the major cause of mortality worldwide and although cardiovascular events are more frequent after the fifth decade of life, there is evidence that their precursors have origin in childhood¹. Individuals with Down syndrome (DS) show an up to sixteen-time higher risk of mortality for cardiovascular diseases². While the incidence of congenital heart defects in the general population is of 0.8%, approximately 40%-65% of individuals with DS develop the disease³. The development of congenital heart defects is multifactorial and under the interference of molecular and morphological signaling. Additionally, the incidence of atrioventricular and ventricular septal defects is of 45% and 35% in patients with DS³, respectively.

Also, the risk of persistent pulmonary hypertension in neonates is 5.2% higher for children with DS in comparison to the general population^{3,4}.

Among the major cardiovascular risk factors, we should point out high blood pressure (BP) and sedentary lifestyle. Some studies have proven that both risk factors show strong tracking from childhood to adulthood⁵⁻⁸ and this suggests that there should be incentives for their reduction from early ages.

BP control is related to lifestyle changes including increasing physical activity⁹. Few studies correlating the effect of physical training on the cardiovascular response of individuals with DS are available; therefore, the specificities of physical exercises should be carefully verified for this population. Kelley et al¹⁰ conducted a meta-analysis involving non-disabled children and adolescents and demonstrated that short-term physical exercises did not lead to reductions in resting SBP and DBP.

Nonetheless, McDonnell et al¹¹ showed that regular physical exercise is associated with a beneficial vascular profile, which is explained by lower large artery stiffness in older individuals, but lower peripheral vascular resistance in young individuals.

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The literature points to the benefits of an active lifestyle for the general population. However, the population with DS has a less active lifestyle than do individuals without DS. This may be harmful to the health and autonomy of this population^{12,13}.

The increase in life expectancy of this population makes the prevention of secondary diseases increasingly more important. Therefore, we hypothesized that physical training (aerobic and resistance) could reduce blood pressure levels and thus improve and/or prevent the development of cardiovascular diseases in individuals with DS. For this reason, knowing the importance of a physically active lifestyle for BP control and for the prevention of cardiovascular diseases, the objective of this study was to investigate the effects of aerobic and resistance training on BP values and hemodynamic variables in young individuals with DS after the training period.

Methods

Participants

Twenty nine young individuals of both genders (20 boys and 9 girls) with Down syndrome and a mean age of 15.7 ± 2.82 years participated in the study. Subject selection was made by inviting all young individuals with DS aged between 12 and 20 years from 3 institutions in the city of Londrina/State of Parana/ Brazil, which provide care for intellectually disabled individuals. Those presenting with orthopedic or cardiac problems; using medications that could affect the heart rate; and those presenting with severe or profound intellectual disability that could affect their understanding and/or ability to perform the procedures were excluded from the study. After receiving explanations on the terms of the research, their parents and/or guardians gave written informed consent. The study was approved by the Research on Humans Ethics Committee, *Universidade Estadual de Londrina*, under opinion number 93.680/2012.

The participants were divided into two groups, according to their availability to attend the physical exercise program: aerobic training group ($n = 14$, of which 4 were girls and 10 were boys); and resistance training group ($n = 15$, of which 5 were girls and 10 were boys).

Initially, there was a control group; however, the individuals from this group did not attend the second assessment visit, and therefore the control group was excluded from the analysis.

Training programs

The aerobic and resistance training programs consisted of 12 weeks with 50-minute-duration sessions.

The aerobic training was performed three times a week in a treadmill and bicycle ergometer (15 minutes each), at an intensity between 50% and 70% of the HR reserve for 30 minutes, preceded by a 10-minute warm-up (articulations and stretching) and followed by 10 more minutes of recovery (stretching). The intensity was monitored by a Polar FT2 heart rate monitor. The HR_{max} used for the calculation of HR reserve

was obtained by means of a maximal exercise test validated for individuals with DS¹⁴. This test started at a 4 km/h speed and 0% inclination for two minutes. Every two minutes the treadmill inclination was increased by 2.5% up to 12.5%. Thereafter, the speed was raised by 1.6 km/h at every minute until volitional fatigue. The test was performed on a treadmill (INBRAMED, model 10.200) with the use of a portable metabolic measurement system (Cosmed k4b2, Italy).

The resistance training consisted of 9 exercises performed in three sets of 12 repetition-maximum, with a 1-minute interval between the sets and 3-minute intervals between exercises. The following series of exercises was proposed: chest press machine; leg extension machine; lat pull down; biceps cable curl; standing leg curl with ankle weights; cable triceps extension; calf raises with ankle weights; dumbbell front raise and abdominal exercises. The two first sessions were for adaptation to the exercise training with low loads and, subsequently, the load used was estimated by observing the participant's ability to perform the exercise in 12 repetitions. Load progression was spontaneous, with increases made whenever the participant was able to perform the three sets of twelve complete repetitions¹⁵.

To participate in the study, the individuals showed a medical clearance certificate for the practice of physical exercises. Additionally, the attendance rate was of at least 75% of the program for all participants, and therefore, none was lost to follow-up. All attended the two assessment visits proposed.

Blood pressure

Blood pressure was monitored by a Finometer™ (Finapres Medical System, BV, The Netherlands) device before and after the training program. Continuous digital electrocardiographic monitoring and noninvasive cardiovascular hemodynamic monitoring by digital infrared photoplethysmography were performed for 15 minutes with the individual in the sitting position.

For the acquisition of pressure curves, a small sensor was placed around the middle phalanx of the left index finger, taking into consideration the participant's age, body mass, height and gender. Body mass (BM) was expressed in kilograms and measured in a digital scale to the nearest 100 grams; height, in meters, was measured in a stadiometer to the nearest 0.1 centimeter; a 2-m flexible tape measure was used for the measurement of the abdominal circumference (AC). The following hemodynamic variables were considered for the analyses: systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR), cardiac output (CO), peripheral vascular resistance (PVR) and stroke volume (SV); the latter was obtained using the formula $SV = CO/HR$. A researcher blind to the groups performed the assessments and analysis of variables.

Statistical analyses

Data are presented as means and standard deviation of the mean. The Shapiro-Wilk test was used to check the normality of data. The two-way ANOVA for repeated measures was used for the comparison of hemodynamic variables pre- and

post-aerobic or resistance training. The Pearson's correlation coefficient was used to correlate the hemodynamic variables with age, body mass and height. Data were analyzed by the SPSS version 18.0 software; in all analyses, the significance level was set at 5%.

Results

Anthropometric data of the groups obtained before the intervention are shown in Table 1. No BP variables or hemodynamic variables showed statistically significant differences ($p > 0.05$) between the groups at the pre-training timepoint.

Data presented in Table 2 show a significant reduction ($p < 0.05$) of systolic, diastolic and mean blood pressure after aerobic and resistance training. No interaction was observed between the factor time and group for variables SBP ($p = 0.20$), DBP ($p = 0.53$) and MBP ($p = 0.58$).

Data regarding heart rate, stroke volume, cardiac output and peripheral vascular resistance are shown in Table 3. No statistically significant differences were found for these variables between timepoints pre- and post-exercise in both groups.

Finally, the Pearson's correlation test between anthropometric, hemodynamic and blood pressure variables did not show significant values for any of the two groups studied.

Discussion

The major finding of the present study suggests a chronic hypotensive effect of aerobic and resistance exercise on young individuals with DS. Nonetheless, the findings of the present study corroborate those of several trials investigating the effects of exercise on blood pressure of non-disabled individuals, which usually show BP reduction after physical

– especially aerobic, training. For resistance exercises, the few studies conducted also point to a BP reduction effect¹⁵⁻¹⁸ albeit less consistently in comparison to aerobic exercises.

Despite the paucity of studies investigating the effect of exercises on blood pressure of individuals with DS, the literature shows some that address aspects of blood pressure and the vascular system in this population. According to Rodrigues et al¹⁹, although individuals with DS show early aging in several organ systems, no difference was observed regarding aortic artery stiffness, which is related to several risk factors for CVD, including high BP, in individuals with DS in comparison to individuals without this condition.

Some studies have found that individuals with DS have chronic hypotension, i.e., blood pressure levels lower than those of normotensive individuals without the syndrome¹⁹⁻²¹. However, there is evidence that deaths related to cardiovascular diseases are more common in individuals with DS than in the general population^{2,22}.

Although BP levels of individuals with and without DS have not been compared in this study, the mean SBP and DBP found for the participants were considered within normal limits²³. Additionally, the baseline levels of SBP, DBP and MBP were similar for both groups.

The guidelines suggest that increasing physical activities contributes to the primary and secondary prevention of arterial hypertension¹⁵. However, according to Cornelissen and Smart¹⁸, the effect of training on the magnitude of BP reduction may vary according to the modality of exercise (aerobic or resistance), duration, intensity, and frequency of training. Our findings corroborate these authors' recommendation of physical exercises for BP control¹⁸ based on the finding that aerobic exercises are effective in BP reduction, as are resistance exercises, which, albeit providing lower reductions in comparison to aerobic exercises, still play

Table 1 – Anthropometric data of participants

	Aerobic training (n = 14)	Resistance training (n = 15)
Body mass (kg)	61.43 ± 11.6	52.7 ± 10.0
Height (cm)	151.7 ± 8.11	150.4 ± 7.0
BMI (kg/m ²)	26.61 ± 4.36	23.3 ± 4.3
Abdominal circumference (cm)	86.8 ± 11.1	77.5 ± 9.2 ¥

¥ Significant difference between groups – $p < 0.05$.

Table 2 – Blood pressure values before and after training

Variables	GrType of Training A Aerobic			Training Group Resistance					
	Pre	Post	Δ	Pre	Pós	Δ	Time p	Time x group p	Group p
SBP (mmHg)	119.6 ± 11.46	110.4 ± 11.7*	-9.3 ± 8.8	113.19 ± 13.04	107.04 ± 10.41*	-6.2 ± 12.0	0.001	0.05	0.03
DBP (mmHg)	77.27 ± 4.73	72.66 ± 6.69*	-4.6 ± 6.9	76.98 ± 8.10	72.23 ± 8.30*	-4.8 ± 10.2	0.03	0.53	0.98
MBP (mmHg)	92.58 ± 5.40	88.35 ± 7.37*	-4.2 ± 7.3	91.74 ± 8.74	86.75 ± 8.38*	-5.0 ± 9.7	0.01	0.58	0.74

SBP: systolic blood pressure; DBP: diastolic blood pressure; MBP: mean blood pressure. * significant difference between pre-training and post-training timepoints – $p < 0.05$.

Table 3 – Values of hemodynamic variables before and after training

Variables	Training Group Aerobic		Training Group Resistance		Time p	Time x group p	Group p
	Pre	Post	Pre	Post			
CO	2.97 ± 0.71	3.80 ± 0.81	2.76 ± 1.02	3.32 ± 1.05	0.60	0.98	0.20
PVR (mmHg.min.l)	32.91 ± 8.54	24.07 ± 4.48	36.62 ± 10.92	28.56 ± 9.64	0.22	0.93	0.07
HR (bpm/min)	81 ± 11	82 ± 11	84 ± 10.04	84 ± 9.34	0.93	0.58	0.31
SV (ml)	0.037 ± 0.00	0.047 ± 0.01	0.032 ± 0.01	0.040 ± 0.01	0.43	0.77	0.17

CO: cardiac output; PVR: peripheral vascular resistance; HR: heart rate; SV: stroke volume.

an important role in BP control. Thus, for this population, resistance training showed significant reductions in blood pressure levels (SBP = -6.2 mmHg; DBP = -4.8 mmHg; MBP = -4.2 mmHg). However, in addition to bringing benefits to blood pressure responses, resistance training has been considered safe for individuals with DS because it improves strength, balance and body composition²⁴.

As regards the chronic antihypertensive mechanisms of exercise, Pescatello et al²⁵ found a reduction in peripheral vascular resistance as the major mechanism, which is possibly mediated by neuro-humoral and structural adaptations. Reduction in vasoconstrictors such as endothelin-1, and elevation in vasodilators such as nitric oxide have been pointed as neurohumoral adaptations to physical exercises^{26,27}.

Although several mechanisms and hemodynamic adaptations have been pointed in response to the chronic effects of aerobic and resistance training on BP, Cornelissen and Fagard²⁸ conducted a meta-analysis and showed that the hemodynamic mechanisms in response to aerobic training resulted from a significant reduction of peripheral vascular resistance (PVR), with no changes in the cardiac output (CO). This can be explained by the increased SV, which is counterbalanced by decreased HR.

In the present study, no significant changes were observed for peripheral vascular resistance in any of the groups (aerobic and resistance training) after the 12-week training.

The adaptations in BP found in the present study may be important for individuals with DS, because, as Hu et al²⁹ suggest, these individuals may have a higher incidence of cardiovascular risk factors such as a low cardiorespiratory capacity and obesity. In this context, many studies have advanced in relation to the influence of exercise on the physical fitness of young individuals with DS, and usually show positive results regarding their cardiopulmonary capacity, strength and body composition^{24,30-34}. Therefore, the findings of the present study in relation to the chronic reduction of blood pressure after an intervention program contribute with more information on the potential benefits of physical exercises for this population.

Although the physical training program has provided significant adaptations of blood pressure, some limitations should be pointed out. First, the number of individuals in each group was small, and this may have hindered some analyses. Additionally, the non-randomized division of intervention

groups may have interfered in the results. Nonetheless, our findings may contribute to a better understanding of the physiological adaptations to physical exercises in young individuals with DS, in addition to stressing the importance of this practice for the health of this population.

Conclusion

By means of the interventions performed, the present study demonstrated that 12 weeks of either aerobic or resistance training provided significant reductions in SBP, DBP and MBP of young individuals with DS. The adaptations found are believed to significantly help control BP and prevent the risk of developing cardiovascular diseases.

Therefore, the implementation of either aerobic or resistance training programs and practice of physical exercises is suggested for young individuals with DS as a means of preventing cardiovascular risks. For these individuals, maintaining a physically active lifestyle should be seen as a strategy that can contribute significantly to improve a sedentary lifestyle and obtain several health benefits.

Author contributions

Conception and design of the research: Seron BB, Goessler KF, Modesto EL, Greguol M. Acquisition of data: Seron BB, Goessler KF, Modesto EL, Almeida EW, Greguol M. Analysis and interpretation of the data: Seron BB, Goessler KF, Modesto EL, Almeida EW, Greguol M. Statistical analysis: Goessler KF. Writing of the manuscript: Seron BB. Critical revision of the manuscript for intellectual content: Seron BB, Goessler KF, Greguol M.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

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References

1. Jonatan RR, Ortega FB. Physical activity and cardiovascular disease risk factors in children and adolescents. *Curr Cardiovasc Risk Rep.* 2009;3:281-7.
2. Hill DA, Gridley G, Cnattingius S, Mellemkjaer L, Linet M, Adami HO, et al. Mortality and cancer incidence among individuals with Down syndrome. *Arch Intern Med.* 2003;163(6):705-11.
3. Al-Bitagi MA. Echocardiography in children with Down syndrome. *World J Clin Pediatr.* 2013;2(4):36-45.
4. Weijerman ME, Van Furth AM, Van der Mooren MD, Van Weissenbruch MM, Rammelo L, Broers CJ, et al. Prevalence of congenital heart defects and persistent pulmonary hypertension of the neonate with Down syndrome. *Eur J Pediatr.* 2010;169(10):1195-9.
5. Pate RR, Baranowski T, Dow M, Trost SG. Tracking of physical activity in young children. *Med Sci Sports Exerc.* 1996;28(1):92-6.
6. Mokdad AH, Serdula MK, Dietz WH, Bowman BA, Marks JS, Koplan JP. The continuing epidemic of obesity in the United States. *JAMA.* 2000;284(13):1650-1.
7. Telama R, Yang X, Viikari J, Välimäki I, Wanne O, Raitakari O. Physical activity from childhood to adulthood: a 21-year tracking study. *Am J Prev Med.* 2005;28(3):267-73.
8. Chen X, Wang Y. Tracking of blood pressure from childhood to adulthood: a systematic review and meta-regression analysis. *Circulation.* 2008;117(25):3171-80.
9. Blumenthal JA, Siegel WC, Appelbaum M. Failure of exercise to reduce blood pressure in patients with mild hypertension: results of a randomized controlled trial. *JAMA.* 1991;266(15):2098-104.
10. Kelley GA, Kelley KS, Tran ZV. The effects of exercise on resting blood pressure in children and adolescents: a meta-analysis of randomized controlled trials. *Prev Cardiol.* 2003;6(1):8-16.
11. McDonnell BJ, Maki-Petaja MK, Munnery M, Yasmin, Wilkinson IB, Cockcroft JR, et al. Habitual exercise and blood pressure: age dependency and underlying mechanisms. *Am J Hypertens.* 2013;26(3):334-41.
12. Balic MG, Mateos EC, Blasco CG, Fernhall B. Physical fitness levels of physically active and sedentary adults with Down syndrome. *Adapt Phys Activity Quarterly.* 2000;17:310-21.
13. Dodd KJ, Shields N. A systematic review of the outcomes of cardiovascular exercise programs for people with Down syndrome. *Arch Phys Med Rehabil.* 2005;86(10):2051-8.
14. Fernhall B, Millar AL, Tymeson GT, Burkett LN. Maximal exercise testing of mentally retarded adolescents and adults: reliability study. *Arch Phys Med Rehabil.* 1990;71(13):1065-8.
15. American College of Sports Medicine. *ACSM's Guidelines for exercise testing and prescription.* 8th ed. Baltimore; 2009.
16. Fagard RH. Exercise is good for your blood pressure: effects of endurance training and resistance training. *Clin Exp Pharmacol Physiol.* 2006;33(9):853-6.
17. Cardoso CG, Gomides RS, Queiroz AC, Pinto LG, Lobo FS, Tinucci T, et al. Acute and chronic effects of aerobic and resistance exercise on ambulatory blood pressure. *Clinics (Sao Paulo).* 2010;65(3):317-25.
18. Cornelissen VA, Smart NA. Exercise training for blood pressure: a systematic review and meta analysis. *J Am Heart Assoc.* 2013;2(1):e004473.
19. Rodrigues AN, Coelho LC, Gonçalves WL, Gouvêa SA, Vasconcellos MJ, Cunha RS, et al. Stiffness of the large arteries in individuals with and without Down syndrome. *Vasc Health Risk Manag.* 2011;7:375-81.
20. Richards BW, Enver F. Blood pressure in Down's syndrome. *J Ment Defic Res.* 1979;23(2):123-35.
21. Morrison RA, McGrath A, Davidson G, Brown JJ, Murray GD, Lever AF. Low blood pressure in Down's syndrome: a link with Alzheimer's disease? *Hypertension.* 1996;28(4):569-75.
22. Day SM, Strauss DJ, Shavelle RM, Reynolds RJ. Mortality and causes of death in persons with Down syndrome in California. *Dev Med Child Neurol.* 2005;47(3):171-6.
23. World Health Organization (WHO). *A Global brief on hypertension: silent killer, Global public health crisis* [Online]. [Accessed on 2014 June 10]. Available from: http://apps.who.int/isis/bitstream/10665/79059/who/_dco.
24. Modesto EL, Greguol M. Influência do treinamento resistido em pessoas com síndrome de Down – uma revisão sistemática. *Rev Bras Ativ Fis e Saúde Pelotas/RS.* 2014;9(2):153-67.
25. Pescatello LS, Franklin BA, Fagard R, Farquhar WB, Kelley GA, Ray CA; American College of Sports Medicine. American College of Sports Medicine position stand: exercise and hypertension. *Med Sci Sports Exerc.* 2004;36(3):533-53.
26. Kingwell BA, Sherrard B, Jennings GL, Dart AM. Four weeks of cycle training increases basal production of nitric oxide from the fore arm. *Am J Physiol.* 1997;272(3 Pt 2):H1070-7.
27. Maeda S, Miyauchi T, Kakiyama T, Sugawara J, Iemitsu M, Irukayama-Tomobe Y, et al. Effects of exercise training of 8 weeks and detraining on plasma levels of endothelium-derived factors, endothelin-1 and nitric oxide, in healthy young humans. *Life Sci.* 2001;69(9):1005-16.
28. Cornelissen VA, Fagard RH. Effects of endurance training on blood pressure, blood pressure-regulating mechanisms, and cardiovascular risk factors. *Hypertension.* 2005;46(4):667-75.
29. Hu M, Yan H, Ranadive SM, Agiovlaitis S, Fahs CA, Atiq M, et al. Arterial stiffness response to exercise in persons with and without Down syndrome. *Res Dev Disabil.* 2013;34(10):3139-47.
30. Shields N, Taylor NF, Wee E, Wollersheim D, O'Shea SD, Fernhall B. A community-based strength training programme increases muscle strength and physical activity in young people with Down syndrome: a randomised controlled trial. *Res Dev Disabil.* 2013;34(12):4385-94.
31. Casajus J, Pueyo D, Vicente-Rodríguez G, González-Agüero A. Mejoras de la condición cardiorrespiratoria en jóvenes con síndrome de Down mediante entrenamiento aeróbico: estudio longitudinal. *Apunts Med Esport.* 2012;47(174):49-54.
32. Lin HC, Wuang YP. Strength and agility training in adolescents with Down syndrome: a randomized controlled trial. *Res Dev Disabil.* 2012;33(6):2236-44.
33. Gupta S, Rao BK, Kumaran SD. Effect of strength and balance training in children with Down's syndrome: a randomized controlled trial. *Clin Rehabil.* 2011;25(5):425-32.
34. Ordóñez FJ, Rosety M, Rosety-Rodríguez M. Influence of 12-week exercise training on fat mass percentage in adolescents with Down syndrome. *Med Sci Monit.* 2006;12(10):CR416-9.

