

Effects of various physical exercise programs on health parameters in elderly individuals

SAMPAIO AN¹, BRAGA AS², BEZERRA JA³, CASTRO ACM⁴, GONÇALVES LCO⁵, MAGALHÃES-NETO AM⁶, FIDALE TM⁷, BORTOLINI MJS⁸, ABREU LC⁹, SILVA RPM¹⁰

^{1,8,10} Graduate Program in Health Science in the Western Amazon – Federal University of Acre, Rio Branco-AC, BRAZIL.

² Exact and Technological Science Center – Federal University of Acre, Rio Branco-AC, BRAZIL.

³ Health and Sports Science Center - Federal University of Acre, Rio Branco-AC, BRAZIL.

⁴ Northern Educational Union – Rio Branco-AC, BRAZIL.

^{5,6} Graduate Program in Basic and Applied Immunology and Parasitology – Barra do Garças-MT, BRAZIL.

^{5,6} Graduate Program in Physical Education – Federal University of Mato Grosso-MT, BRAZIL.

⁵ Graduate Program in Genetics and Biochemistry – Federal University of Uberlandia-MG, BRAZIL.

^{7,10} Special Academic Unit of Biotechnology, Federal University of Goiás - Catalão-GO, BRAZIL.

⁹ Health Sciences Center, Federal University of Espírito Santo, BRAZIL.

Published online: October 31, 2024

Accepted for publication: October 15, 2024

DOI:10.7752/jpes.2024.10255

Abstract:

This study examines the impact of different physical exercise programs on health variables in elderly individuals. A total of 60 participants were assigned to four groups: resistance training in open-air gyms (GT1, n = 17), aerobic and localized exercises (GT2, n = 11), resistance training in traditional gyms (GT3, n = 17), and a control group (CG, n = 15). Anthropometric, cardiovascular, metabolic, and strength parameters were measured before and after 16-week intervention. The GT1 showed a small effect (Cohen d effect size) on fat percentage, waist-rip ratio (WHR), and upper limb strength (ULS) and a medium effect on lower limb strength (LLS). For the GT2, there was a large effect on the LLS. For the GT3, there was a medium effect on the ULS and a large effect on the LLS. There was a small effect on glycemia in the GT1, a medium effect on glycemia and triglycerides in the GT2, a small effect on total cholesterol in the GT3, and a large effect on glycemia in the CG, where the glucose levels were increased. There were large effects on SBP in the GT2; small effects on SBP, DBP, and HR in the GT3; and small effects on SBP and HR in the CG. The TG, LLS, and ULS variables differed the most for each type of exercise. The three methods proved to be efficient, but some may be preferred over the others based on the patients' health conditions, objectives, or characteristics at the time when the physician assigned them to the program.

Key Words: Health Promotion, Data Mining, Sports Medicine, Metabolism.

Introduction

Population aging coupled with a sedentary lifestyle is one of the major challenges in public health (Veras, 2009). According to WHO data (WHO, 2009), it is estimated that 3.2 million people die each year from physical inactivity. Causes of mortality are increasing by 20% to 30% among underactive individuals (WHO, 2010). Globally, 31.1% of adults are physically inactive, and this percentage increases with age (Hallal et al., 2012). In Brazil, the number of physically inactive individuals in the elderly population has increased, which requires immediate coping and prevention strategies for related health problems to promote active, healthy and independent aging (Mazo et al., 2009). Health intervention strategies adopted in the health system, especially those involving multicompetent actions, including the practice of physical exercise, are effective in increasing the duration of physical activity in the population (Ribeiro et al., 2017).

An increase in the level of physical activity can cause positive effects among individuals at advanced ages; among these effects are improvements in muscular strength and resistance, increased aerobic capacity, greater joint flexibility, better balance and coordination, greater psychological well-being, weight loss and better management of chronic diseases or deficiencies (Santana & Chaves, 2009). However, in studies conducted by Hoehner et al. (2013) in Latin America, there is a lack of evidence on the efficacy of physical activity interventions at the community level. The implementation of programs and actions, particularly actions aimed at elderly people, whether by universities or official bodies working on health promotion, is a new trend in social policies that will have repercussions for new advances and lifestyles (Benedetti et al., 2017). This is supported by the notion that physical activity is the factor that most consistently predicts healthy aging (Costa et al., 2009), and there is strong evidence that it is highly cost effective (WHO, 2014).

For many years, regular physical exercise has ceased to be just a model for increasing athletes' performance and winning titles. In recent decades, it has been used as a study model in several research fields,

from pharmacology, immunometabolism, and nutrition to epidemiological and public health studies, aiming to answer different questions in different experimental conditions and populations (Gonçalves et al, 2012; Lopes et al, 2019). Sportomics was an innovative proposal to represent the immunometabolic characteristics and transformations in the field of action of each exercise modality, not in a predictive way, in laboratories (Gonçalves et al, 2012; Gonçalves et al, 2022; Souza et al, 2024; Prampero et al, 2024). In the present study, a sportomics strategy was used to conduct the exercise in its natural form and in its scope of practice, bringing accurate data and not speculation. When practiced regularly, physical exercise can have beneficial effects on mental, physical, social, and general health. However, when practiced without controlling volume, intensity, recovery, type of movement, and immunometabolic impact, it can be harmful and even fatal, as in the various cases of exercise-induced rhabdomyolysis with permanent loss of renal function. Therefore, understanding the immunometabolic stress generated by each type of exercise and in different populations has become a public health issue (Galvão et al, 2023; Gomes et al, 2023; Silva et al, 2024).

The objective of this study was to analyze the effects of different physical exercise health care programs on the anthropometric, cardiovascular, metabolic and strength variables of elderly participants.

Material & methods

Participants

The study included elderly people of both sexes, aged 60 to 80 years, patients of two-family health units who performed physical activities in the elderly groups, and patients who participated in physical activity programs for elderly people at the Federal University of Acre, all of whom were instructed by physical education professionals.

Procedure/Test protocol/Skill test trial/Measure/Instruments

The study included 82 elderly people divided into the following three experimental groups, allocated according to the modality offered at the family health unit: GT1 (n = 24) training group at open-air gyms - USF (Bairro Calafate); GT2 (n = 17) aerobic and localized exercise training group - USF (Bairro Cadeia Velha); GT3 (n = 25) resistance exercise training group (Active Elderly Extension Program at UFAC) and a control group: CG (n = 16), nonphysical exercise practitioners - USF (Bairro Cadeia Velha). Elderly individuals who had not exercised for at least one month and who were in an acceptable physical condition to participate in the proposed activities were included in the study. Those who had any physical illness or restriction that prevented them from participating in the activities for more than one month were excluded, as were those who attended classes for less than 75% and those who did not attend the assessments. Simple random sampling was used in this study. Weight was used as the variable in this study since it is related to body mass index. A pilot sample of 50 individuals was considered. These results served as guidelines for obtaining the final sample size. A Student's t value of 2.021, a sample variance of 140.12 kg² and a sample error of 5% of the mean were considered, that is, an error = 3.396 with a confidence level of 95%. Anthropometry consisted of measuring weight, height and waist circumference and calculating body mass index (BMI) and the percentage of body fat. The skin folds (SFs) were measured with a Sanny® scientific adipometer, precisely at 1 mm on the right side of the body at four sites (subscapular, triceps, supra-iliac and medial calf). The equation for the prediction of body density (BD) proposed by Petroski (1995) was applied, and for the calculation of fat percentage, the Siri Equation (Siri, 1961) was used. Upper limb strength was measured by a hand grip test with a JAMAR Dynamometer, following the ASHT (Araujo, 2003) guidelines; the participants were evaluated in a seated position with the elbow at 90° without moving it, and the appliance was pressed as hard as possible at the signal of the evaluator. To evaluate the strength and resistance of the lower limbs, the sit-and-stand test was performed for 30 seconds, during which the patient sat in a chair, arms crossed against the chest, and at the evaluator's signal, the patient reached and sat down completely for a maximum of 30 seconds (Rikli & Jones, 1999).

The experimental groups were subjected to 16 weeks of training, with three weekly sessions of an average duration of 60 minutes per session. GT1 performed exercises at outdoor gyms, which is defined as a set of gym equipment set up in easily accessible spaces. The participants used the weight of their own body as they followed the exercise movements. Treatment consisted of 30 minutes of walking simulation, riding simulation, leg pressing, seated rowing, vertical rotation, shoulder development and combined triple ski in a circuit. After that, they participated in recreational activities or group dynamics, followed by stretching. GT2 performed aerobic exercises such as dancing and walking for 20 minutes, followed by exercises for the upper and lower limbs for 30 minutes and stretching. GT3 performed a resistance exercise program at the gym of the Federal University of Acre, consisting of exercises for the upper and lower limbs with mono- and biarticular movements. The activities were performed for a total of sixty minutes, starting with a 10-minute walk on the treadmill and resistance training in the form of a circuit composed of 10 exercises with two sets of 10 to 12 maximum repetitions and 60 seconds of rest between bench press, slope supine, front pulley, triceps pulley, biceps screw, 45° leg press, knee extension, knee flexion, standing plantar flexion and straight abdominal crunches on the ground. The weight loads were adjusted according to the individual progress of each participant. The CG did not practice physical exercise during the intervention period.

Data collection and analysis / Statistical analysis

Initially, descriptive statistics were performed on the data, with position measurements (mean, median, mode, and percentiles) and dispersion (amplitude, variance, standard deviation, and standard error).

Afterward, univariate analysis of these data was performed using the Shapiro–Wilk normality test and Kolmogorov–Smirnov test. The equal variance test was applied if the normality test resulted in a normal distribution ($P > 0.05$). For results with $P > 0.05$, the paired Student's *t* test was used; if $P \leq 0.05$, the paired Student's *t* test was used, followed by the nonparametric Mann–Whitney test. If the Shapiro–Wilk test indicated a nonnormal distribution ($P \leq 0.05$), the nonparametric Mann–Whitney test was applied directly.

Nevertheless, in the univariate analysis, one-way repeated-measures ANOVA was performed because the same individuals from different time points were included in each group. Then, the percentage variation was calculated. Next, multivariate data analysis was performed using data mining and machine learning techniques. In this phase, to seek a bivariate measure between the data, because the observations contain quantitative values, the Pearson and Spearman correlation tests were applied, with the Pearson correlation being used for a visual analysis using the correplot (correlation plot) strategy and as an initial measure for the following machine learning analyses. The following are exploratory models of machine learning: CLUSTER—classical clustering (an agglomerative hierarchical method) and ORDINATION—principal component analysis (PCA).

The Z score was previously applied to adjust observation measurement units, and the Fruchterman–Reingold algorithm was applied with the Euclidian similarity index (Fruchterman & Reingold, 1991; Karmen et al., 2019). Cohen's Equations (Cohen, 1992) were used to calculate the effect size for all variables to obtain Cohen's *d* and *r* values (Supp. Table 1): where *M* represents the means of the observations and *SDs* are their respective standard deviations. SigmaPlot 14.5 (Academic Perpetual License - Single User – ESD Systat® USA), R and R Studio (Free version for Windows), AcaStat 10.0 (Free version for Windows) and Past 4.03 (Free version for Windows) were used to carry out the different statistical tests and make the graphs.

Ethical aspects

The project was approved by the Ethical Committee (UNINORTE; Registration No. 59873816.9.0000.8028).

Results

The study began with 82 elderly people who agreed to participate in the study who were distributed in groups according to the criterion of proximity between residence and place of practice. Before the beginning of the interventions, the elderly individuals completed anamnesis fact sheets on their general health status and disease history, such as hypertension and diabetes. During the interventions, the sizes of the groups decreased due to participants dropping out, having disease effects and attending less than 75% of the classes, as shown in the flowchart (Figure 1).

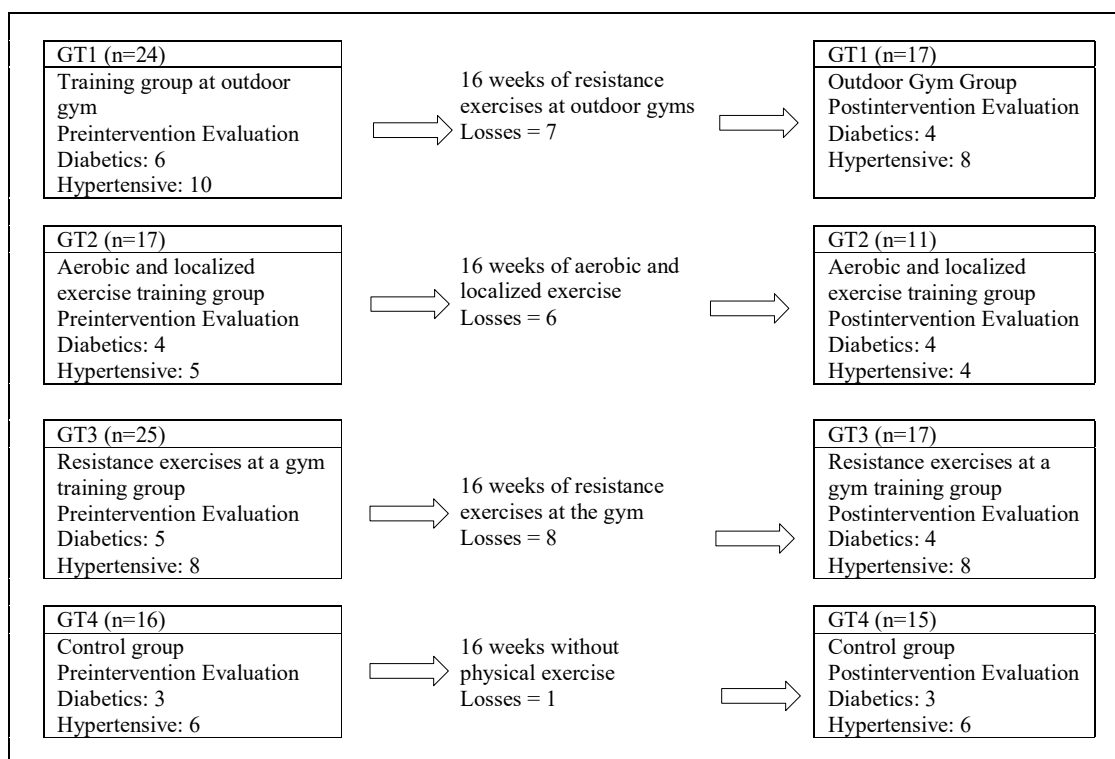


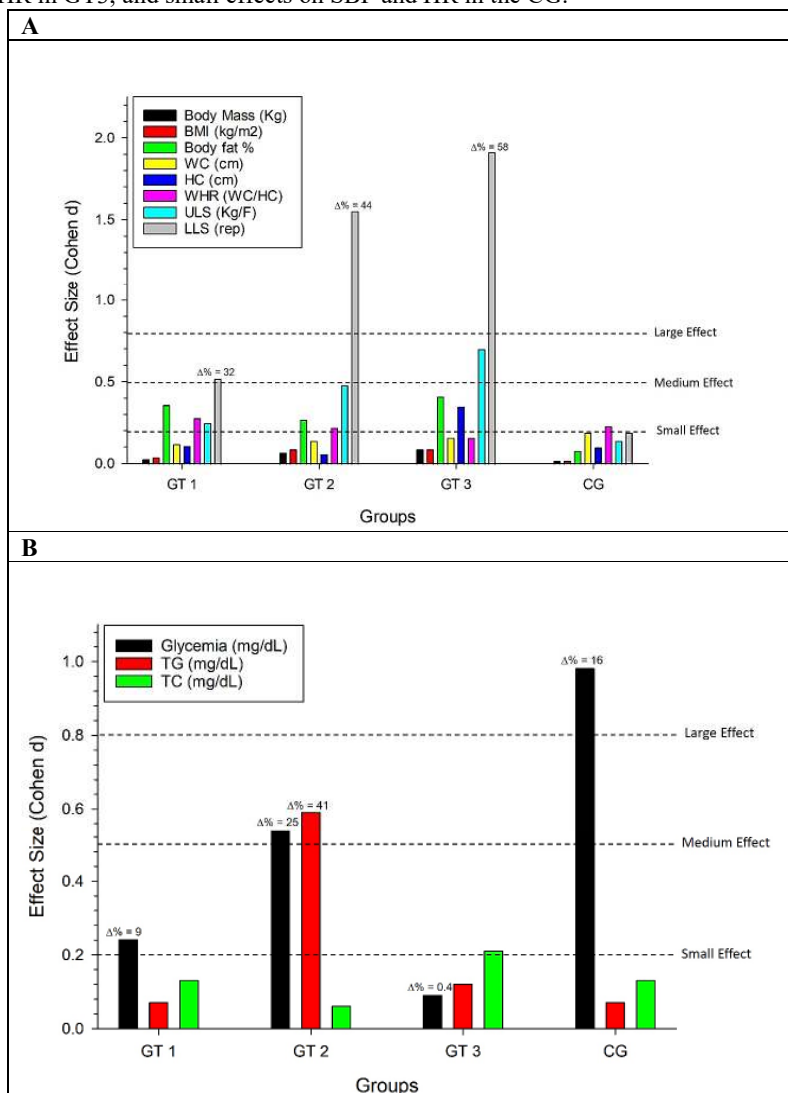
Figure 1. Participation flowchart according to study groups.

Supplementary Table 2 describes the characteristics of age, weight, BMI and sex of the elderly individuals according to their distribution in the treatment and control groups.

Supplementary Table 3 shows the values obtained for the anthropometric and physical conditioning variables before and after the intervention in each group. Taking into account classical tests such as the t test between two means and ANOVA between three or more, there was only a significant difference in the ULS between the post- and pre-GT3 results, in the LLS between the post- and pre-GT2 results, and in the LLS between the post- and pre-GT3 results. There was also a significant difference in the LLS between the CG and GT1. However, more holistic and integrated results will be observed in future tests.

Based on the data from the tests mentioned above, Supplementary Table 4 shows a significant difference in glycemia between the pre- and postintervention periods in both GT2 and the CG, as well as more accurate analyses during the study. For classical analysis of the variables, Supplementary Table 5 presents the results of the cardiovascular variables, including systolic blood pressure, diastolic blood pressure, heart rate, and double product, but there were no significant differences between pre- and postintervention periods or among groups. These results will be questioned after subsequent analyses within the present study.

Figure 2 is shown in Graph A, which shows the morphofunctional variables for GT1, and a small effect on fat percentage, WHR, and ULS, and a medium effect on LLS. For GT2, there was a small effect on fat percentage, WHR, and ULS and a large effect on LLS. For the GT3 group, there was a small effect on the percentage of fat and HC, a medium effect on the ULS, and a large effect on the LLS. In Graph B, biochemical variables are shown, revealing a small effect on glycemia in GT1, a medium effect on glycemia and triglycerides in GT2, a small effect on total cholesterol in GT3, and a large effect on glycemia in the CG, specifically an increase in glucose levels. For the cardiovascular variables (C), there was a small effect on SBP and HR in GT1; a small effect on DBP, HR, and DP; a large effect on SBP in GT2; a small effect on SBP, DBP, and HR in GT3; and small effects on SBP and HR in the CG.



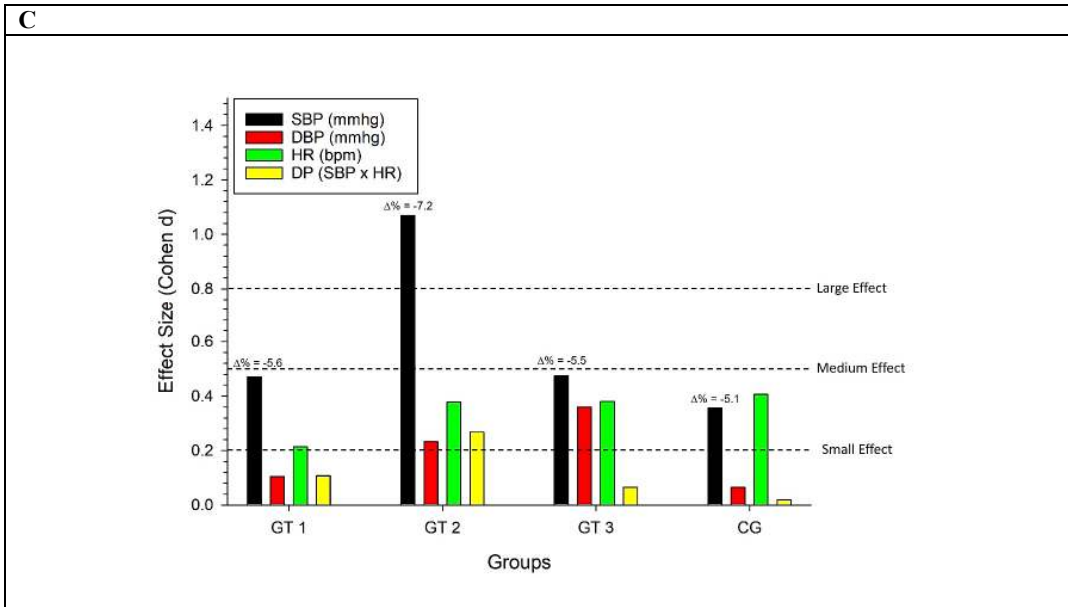


Figure 2. Effect size of different forms of exercise on morphofunctional (A), biochemical (B) and cardiovascular (C) variables.

To provide a holistic view of the data, Figure 3 presents the associations between the percentage variations of the study variables, with the Pearson correlation being calculated as quantitative data. The correlation coefficients representing inverse correlations between BMI ($P = 0.0007$) and body fat percentage ($P = 0.007$) with the ULS are highlighted in yellow.

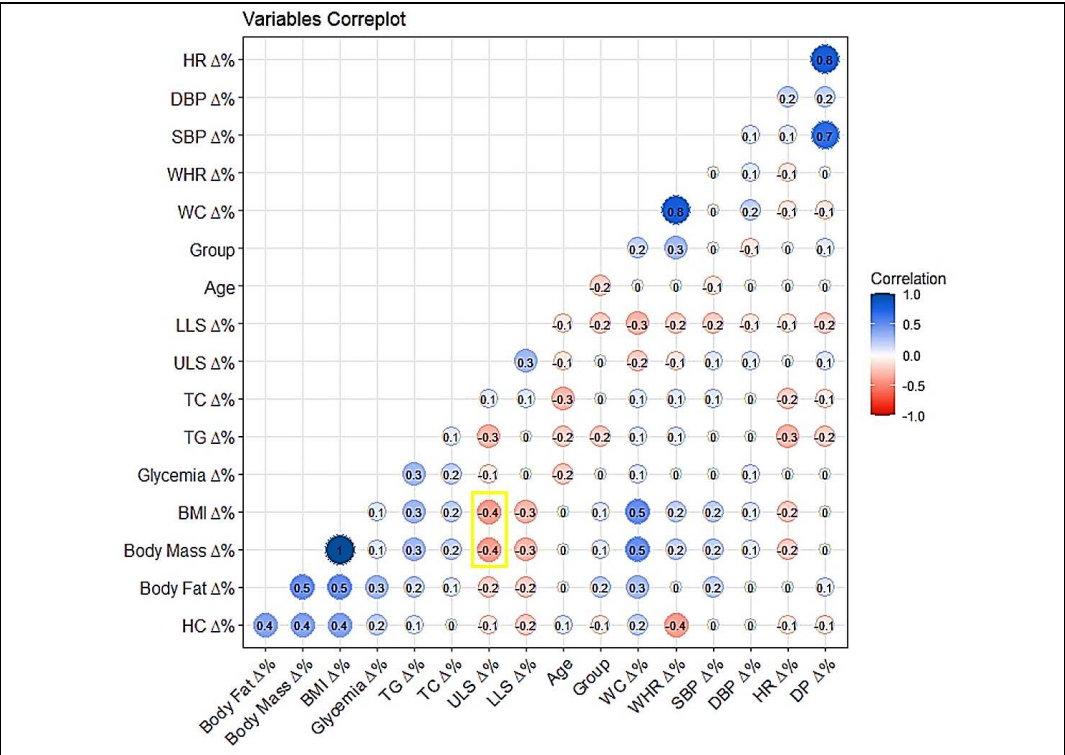


Figure 3. Correlation coefficients between percentage changes in study variables.

Figure 4 shows through principal component analysis (A), cluster analysis (B) and network plot analysis with the Fruchterman-Reingold algorithm (C) that the TG, LLS and ULS variables differed the most for each type of exercise intervention in the present study.

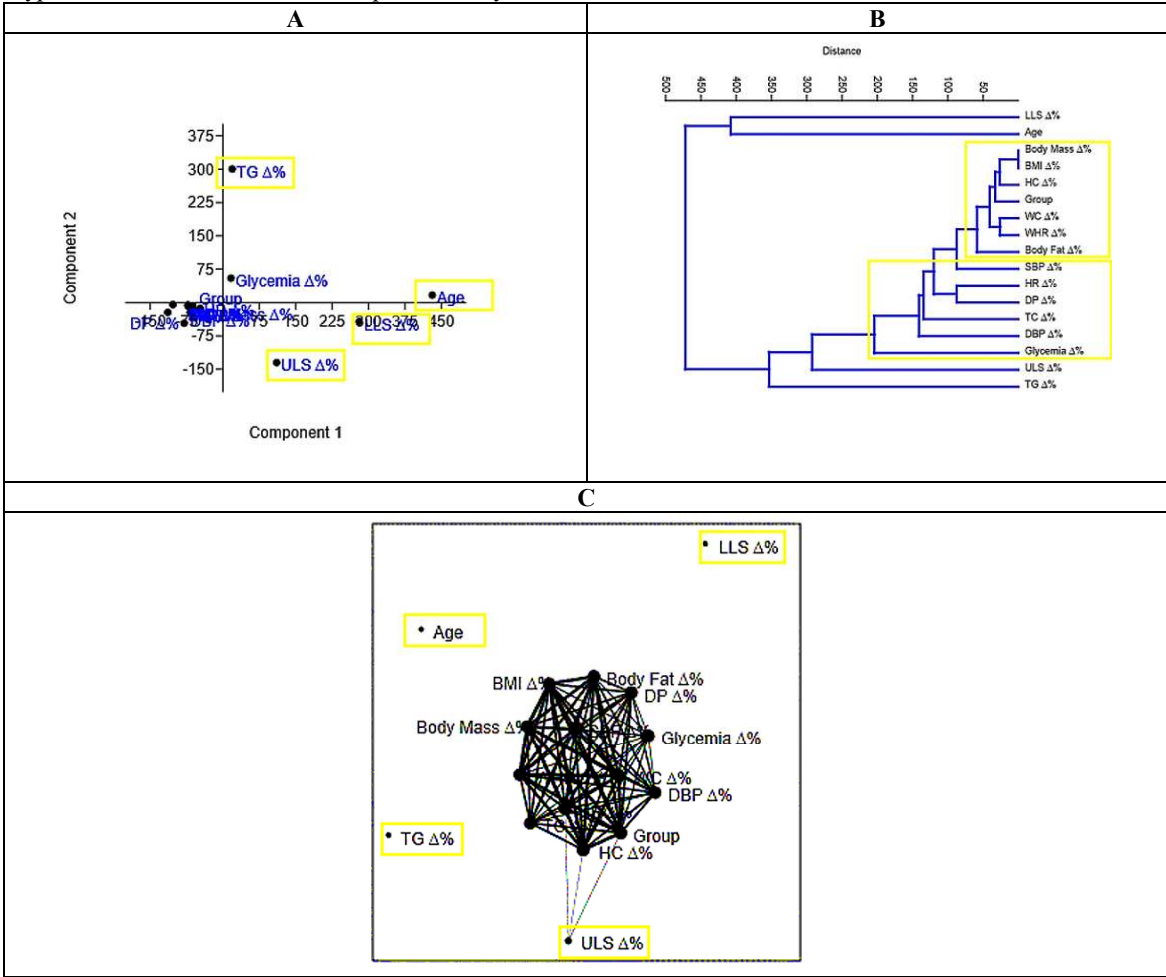


Figure 4. Assessment of similarity in the trends of variables after applying the Euclidean similarity index by PCA (A), cluster analysis (B) and network plot (C), the latter being after applying the Fruchterman-Reingold algorithm.

The results presented in Figure 5A, which revealed different trends between the four groups, indicate that the results for all the variables in any of the groups did not significantly correlate with those for all the variables in the control group. In addition, this finding is robust given that all forms of exercise caused changes in morphofunctional, biochemical and cardiovascular parameters in relation to those of the control group but with specificities within each intervention group.

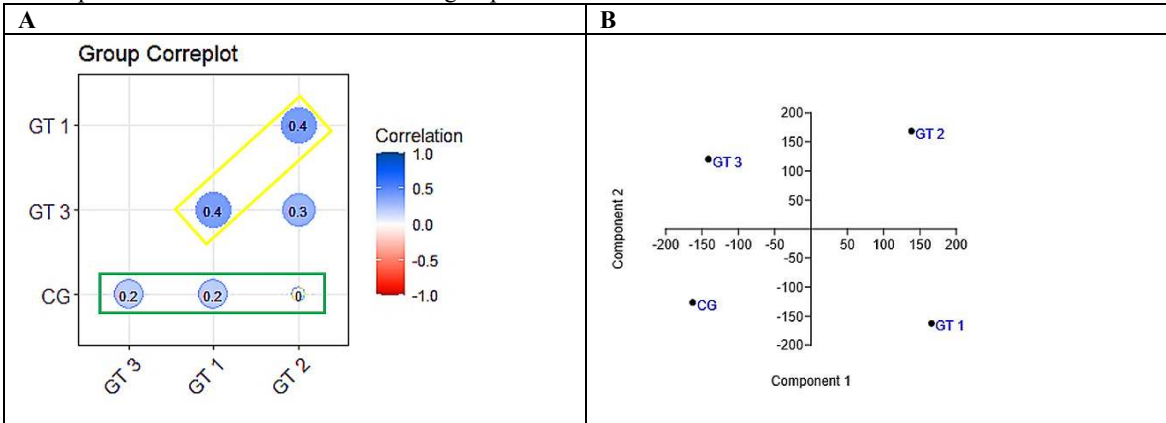


Figure 5. Observation of all variables in sequence to compare correlations (A) and analyze main components (B) between the groups.

Dicussion

The initial BMI values presented by the experimental and control groups indicated that the participants were overweight, which presents greater risks for the development of cardiovascular diseases and is considered a strong indicator of mortality (MacMahon et al., 2009).

After the interventions, all the parameters in the intervention groups showed a decreasing trend, which is contrary to the increasing trend observed in the parameters of the control group. The results of this study corroborate those of Filho et al. (2011), who reported that although the proposed exercise program significantly reduced the BMI of elderly participants, they still had values above the mean for this population. These findings indicate the importance of continuity in exercise programs and possible adjustments of volume and intensity in the activities to obtain desirable outcomes. The percentage of fat decreased in the experimental groups after the interventions, with effects above 0.2 for all groups, demonstrating that participating in physical activity may be an important element in maintaining ideal fat levels. Additionally, in accordance with Aoyagi and Shephard (2010), the accumulation of body fat (% fat and sum of skin folds) related to aging is more strongly associated with lifestyle and physical activity level than with aging itself.

GT3 presented greater fat loss (-7.72%) than did the other groups, possibly due to the effect of resistance training. Bureson et al. (1998), when comparing resistance exercises with aerobic exercises, reported that resistance exercises may cause greater disturbance in homeostasis than aerobic exercises, suggesting that, due to the high intensities involved, they could require greater energy expenditure both during exercise and recovery. It is believed that this effect is due to the reduction in body fat deposits associated with weight training, a product of postexercise oxygen consumption caused by high-intensity stimulation, which could increase lipid oxidation afterwards (Poehlman & Melby, 1998).

Waist circumference tended to decrease in the treatment groups, and this trend was opposite in the control group. These results suggest that participation in activities was the contributing factor for this decrease since the waist circumference of the CG increased during this period. Notably, fat accumulation in this age group occurs more commonly in the intra-abdominal region than in the subcutaneous region (Cetin & Nasr, 2014). Hip circumference decreased more in GT3 than in GT1 and was fivefold greater in GT3 than in GT2. Thus, participating in physical exercise can be considered a protective factor since abdominal obesity is more consistently related to a metabolic profile that predicts the risk of cardiovascular disease than is general obesity (Rexrode et al., 1998) and has an important association with physical disability (Angleman et al., 2006).

In relation to the percentage variation in force, both the ULS and LLS showed an increase in order of magnitude, being lower in GT1, intermediate in GT2 and greater in GT3. Looking at the extent of the effect, overall, LLS had the greatest effect, particularly having a medium effect in GT1 and a large effect in groups GT2 and GT3. These findings are possibly explained by the fact that, generally speaking, higher intensity loads provide a significantly greater increase in force gains compared to lower loads due to neural and hypertrophic adaptations from the type of training (Silva & Farinatti, 2007). Vale et al. (2006) observed significant differences in the muscular strength of elderly women who practiced bodybuilding for 16 weeks compared to the control group. Souza et al. (2014), when comparing the effect of different interventions on the maximum strength of elderly women, concluded that the bodybuilding group presented the highest values compared to the water gymnastics participants and to those not practicing physical exercise.

Similar results were found in the study by Queiroz and Munaro (2012), who reported resistance training for a period of eight weeks, with 50% to 70% of the elderly women experiencing a significant increase in muscular strength according to the 1RM. For biochemical variables, the GT1 and GT2 groups showed more prominent increases in glycemia and triglycerides than did GT1, with greater effects in the GT2 group, perhaps due to greater metabolic mobilization of energy substrates without major changes in total cholesterol. Although it has been described in the literature that exercise induces important physiological changes, such as increased glucose uptake by muscles (Teran-Garcia et al., 2005) and increased lipid oxidation (Poehlman & Melby, 1998), which may contribute to a decrease in blood glucose and lipid levels, the applied interventions were not enough to promote significant reductions. The results found in this analysis are supported by the study by Bemben & Bemben (2000), where after the interventions composed of resistance or aerobic exercises, no effect was observed in the lipid profile. Finally, for cardiovascular variables, GT2 showed a greater reduction in the percentage change for SBP (large effect) but with an increase in DBP (medium effects in both groups), which was the opposite trend to that in the other groups. GT2 also had the largest percentage reduction in DP.

In the present study, the objective was to portray the daily realities of the elderly individuals who participated in the research. Therefore, they did not follow a specific diet but rather followed their routine eating habits, which may have influenced the final results. In studies conducted by Stefanick et al. (1998) and Nieman et al. (2002), where groups with a combination of diet and exercise and exercise alone were compared, they found that there was a decrease in LDL and TC concentrations only in the group that performed the combination of diet and exercise.

Finally, it is worth highlighting that unsupervised and exploratory machine learning strategies favor a holistic analysis of results, and in the science of physical education and sports it sets the pace for the future (Galvão et al., 2023; Gomes, et al., 2023; Prampero et al., 2024).

Conclusions/Recommendations

The results of this study indicate that GT2 (group of aerobic and localized exercises) exhibited greater percentage reductions in body mass and BMI. However, GT3 (a group of resistance exercises at gyms) exhibited a greater reduction in fat percentage. GT2 exhibited the greatest decrease in waist circumference, while GT3 exhibited the largest decrease in hip circumference. The three groups exhibited an increase in strength (ULS and LLS). However, in ascending order, GT1 (a group of resistance exercises in outdoor gyms) exhibited the smallest increase, GT2 exhibited an intermediate increase, and GT3 exhibited the greatest increase in strength, with effects considered large in GT2 and GT3. Finally, GT2 exhibited a greater percentage reduction in systolic blood pressure (large effect) and double product (small effect) than did the other groups.

The three methods proved to be efficient, but with indications of preferred methods depending on the patients' health conditions, objectives, or characteristics at the time of the program assignment.

The authors recommend that the same experiment be conducted in different regions of the world and populations to identify whether the results observed in the present study for this age group may differ in different cultures or environments, especially when dealing with elderly populations, where small adjustments may represent greater health, longevity, autonomy, and quality of life.

Declarations

Acknowledgments

We thank the Acre Health Department for approving and supporting the study. Additionally, we thank all the professionals at the family health units for their support and the elderly individuals for agreeing to participate in the experiment.

Author contributions

ANS and RPMS Conceptualization; ANS, ASB, LCOG, AMMN and RPMS Data curation; ANS, ASB, LCOG, AMMN, TMF, MSB, LCA and RPMS Formal analysis; ANS, ATB, JAB, APMC and RPMS Investigation; ANS and RPMS Methodology; RPMS Project administration; All authors Resources; Software; Supervision; Validation; Visualization; Writing - original draft; and Writing - review & editing.

Conflicts of interest

The authors declare that they have no conflicts of interest.

Consent to participate

Informed consent to participate in the study was obtained from the participants.

Availability of data and materials

All tables cited as supplementary tables are available at the following link: DOI: <https://doi.org/10.6084/m9.figshare.25391860>

Funding Not applicable.

References

- Angleman, S. B., Harris, T. B., Melzer, D. (2006). The role of waist circumference in predicting disability in periretirement age adults. *Int J Obes*, 30(2):364–373. <https://doi.org/10.1038/sj.ijo.0803130>.
- Aoyagi, Y., Shephard, R. J. (2010). Habitual physical activity and health in the elderly: The Nakanojo Study. *Geriatr Gerontol Int*, 10(1):S236–S243. <https://doi.org/10.1111/j.1447-0594.2010.00589.x>.
- Araújo, P. M. P. (2003). Introdução à avaliação do membro superior. In: SBTM. Recomendações para avaliação do membro superior. São Paulo: *Sociedade Brasileira de Terapeutas da Mão*. São Paulo, 2003:1-84.
- Bemben, D. A., Bemben, M. G. (2000). Effects of resistance exercise and body mass index on lipoprotein-lipid patterns of postmenopausal women. *J Strength Cond Res*, 14(1):80–86. <https://doi.org/10.1519/00124278-200002000-00014>.
- Benedetti, T. R. B., Gonçalves, L. H. T., Mota, J. A. P. D. S. (2007). Uma proposta de política pública de atividade física para idosos. *Texto Context – Enferm*, 16(3):387–398. <https://doi.org/10.1590/S0104-07072007000300003>.
- Burleson, M. A., Bryant, H. S., Stone, M. H., Collins, M. A., McBride, T. T. (1998). Effect of weight training exercise and treadmill exercise on post-exercise oxygen consumption. *Med Sci Sport Exerc*, 30(4):518–522.
- Cetin, D. C., Nasr, G. (2014). Obesity in the elderly: More complicated than you think. *Cleve Clin J Med*, 81(1):51–61. <https://doi.org/10.3949/ccjm.81a.12165>.
- Cohen, J. (1992). Quantitative methods in psychology. A power primer. *Psychological Bulletin*, 112(1):155-159. <https://doi.org/10.1037//0033-2909.112.1.155>.
- Costa, M. F. F. L., Peixoto, S. V., César, C. C., Malta, D. C., Moura, E. C. (2009). Comportamentos em saúde entre idosos hipertensos, Brasil, 2006. *Rev Saude Publica*, 43(supl 2):18–26. <https://doi.org/10.1590/S0034-89102009000900004>.
- Filho, M. L. M., Rodrigues, B. M., Aidar, F. J., Reis, V. M., Polito, M. D., Venturini, G. P., et al. (2011). Influência dos exercícios aeróbico e resistido sobre perfil hemodinâmico e lipídico em idosos hipertensos. *Rev Bras Ciên e Mov*, 19(4):15–22.

- Fruchterman, T. M. J., Reingold, E. M. (1991). Graph drawing by force-directed placement. *Software Practice and Experience*, 21(11):1129-1164.
- Galvão, A. S., Gomes, M. K. M., Freitas, N. C. S., Macedo, L. S., Oliveira, D. M., Verli, M. V. A., Nahon, R. L. N., Gonçalves, L. C. O., Magalhães-Neto, A. M. (2023). Machine learning in sports medicine: A new approach in human exercise. *Journal of Human Sport and Exercise*, 18(2), 501-508. <https://doi.org/10.14198/jhse.2023.182.19>.
- Gomes, M. K. M., Verli, M. V. A., Macedo, L. S., Galvão, A. S., Freitas, N. C. S., Nahon, R. L., Magalhães-Neto, A. M., Gonçalves, L. C. O. Multivariate analysis by exploratory machine learning model indicates orienteering race as an immunometabolically safe stimulus, but with differences between age groups. *Journal of Physical Education and Sport ® (JPES)*, 23(issue 2): 372 – 378 <https://doi.org/10.7752/jpes.2023.02044>.
- Gonçalves, L. C., Bessa, A., Freitas-Dias, R., Luzes, R., Werneck-de-Castro, J. P. S., Bassini, A., Cameron, L. C. (2012). A sportomics strategy to analyze the ability of arginine to modulate both ammonia and lymphocyte levels in blood after high-intensity exercise. *J Int Soc Sports Nutr*, 9(1):30. <https://doi.org/10.1186/1550-2783-9-30>.
- Gonçalves, L. C. O., Magalhães-Neto, A. M., Bassini, A., Prado, E. S., Muniz-Santos, R., Verli, M. V. A., Jurisica, L., Lopes, J. S. S., Jurisica, I., Andrade, C. M. B., Cameron, L. C. (2022). Sportomics suggests that albuminuria is a sensitive biomarker of hydration in cross combat. *Sci Rep*, 12(1):8150. <https://doi.org/10.1038/s41598-022-12079-7>.
- Hallal, P. C., Andersen, L. B., Bull, F. C., Guthold, R., Haskell, W., Ekelund, U., et al. (2012). Global physical activity levels: Surveillance progress, pitfalls, and prospects. *Lancet*, 380(9838):247–257. [https://doi.org/10.1016/S0140-6736\(12\)60646-1](https://doi.org/10.1016/S0140-6736(12)60646-1).
- Hoehner, C. M., Ribeiro, I. C., Parra, D. C., Reis, R. S., Azevedo, M. R., Hino, A. A., et al. (2013). Physical activity interventions in Latin America: expanding and classifying the evidence. *Am J Prev Med*, 44(3):e31-e40. <https://doi.org/10.1016/j.amepre.2012.10.026>.
- Karmen, C., Gietzelt, M., Knaup-Gregore, P., Ganzinger, M. (2019). Methods for a similarity measure for clinical attributes based on survival data analysis. *BMC Med Inform Decis Mak*, 19(1):195. <https://doi.org/10.1186/s12911-019-0917-6>.
- Lopes, J. S. S., Magalhães-Neto, A. M., Gonçalves, L. C. O., Alves, P. R. L., Almeida, A. C., Andrade, C. M. B. (2019). Kinetics of Muscle Damage Biomarkers at Moments Subsequent to a Fight in Brazilian Jiu-Jitsu Practice by Disabled Athletes. *Front Physiol*, 10:1055. <https://doi.org/10.3389/fphys.2019.01055>.
- MacMahon, S., Baigent, C., Duffy, S., Rodgers, A., Tominaga, S., Chambless, L., et al. (2009). Body-mass index and cause-specific mortality in 900 000 adults: Collaborative analyses of 57 prospective studies. *Lancet*, 373(9669):1083–1096. [https://doi.org/10.1016/S0140-6736\(09\)60318-4](https://doi.org/10.1016/S0140-6736(09)60318-4).
- Mazo, G. Z., Cardoso, A. S., Dias, R. G., Balbê, G. P., Virtuoso, J. F. (2009). Do diagnóstico à ação: grupo de estudos da terceira idade: alternativa para a promoção do envelhecimento ativo. *Rev Bras Ativ Fís Saúde*, 14:65-70.
- Nieman, D. C., Brock, D. W., Butterworth, D., Utter, A. C., Nieman, C. C. (2002). Reducing diet and/or exercise training decreases the lipid and lipoprotein risk factors of moderately obese women. *J Am Coll Nutr*, 21(4):344–350. <https://doi.org/10.1080/07315724.2002.10719233>.
- Petroski, E. L. (1995). Desenvolvimento e validação de equações generalizadas para a estimativa da densidade corporal em adultos. Universidade Federal de Santa Maria [Tese]; 1995.
- Poehlman, E. T., Melby, C. (1998). Resistance training and energy balance. *Int J Sport Nutr*, 8(2):143–159. <https://doi.org/10.1123/ijns.8.2.143>.
- Prampero, S. L., Gonçalves, L. C. O., Mourão, N. R. D., Verli, M. V. A., França, E. L., França, A. H., Magalhães-Neto, A. M. (2024). The double product breakpoint as predictor of stress and the correlation between IL-12 and biomarkers in athletes. *Journal of Physical Education and Sport ® (JPES)*, 24(issue 2):456-463. <https://doi.org/10.7752/jpes.2024.02056>.
- Queiroz, C. O., Munaro, H. L. R. (2012). Efeitos do treinamento resistido sobre a força muscular e a autopercepção de saúde em idosos. *Rev Bras Geriatr e Gerontol*, 15(3):547–553. <https://doi.org/10.1590/S1809-98232012000300015>.
- Rexrode, K. M., Carey, V. J., Hennekens, C. H., Walters, E. E., Colditz, G. A., Stampfer, M. J., et al. (1998). Abdominal Adiposity and Coronary Heart Disease in Women. *JAMA*, 280(21):1843–1848. <https://doi.org/10.1001/jama.280.21.1843>.
- Ribeiro, E. H. C., Garcia, L. M. T., Salvador, E. P., Costa, E. F., Andrade, D. R., Latorre, M. R. D. O., et al. (2017). Avaliação da efetividade de intervenções de promoção da atividade física no Sistema Único de Saúde. *Rev Saude Publica*, 51(56):1–12. <https://doi.org/10.1590/s1518-8787.2017051006654>.
- Rikli, R., Jones, J. (1997). Development and Validation of a Functional Fitness Test for Community-Residing Older Adults. *J Aging Phys Act*, 7:129–161.
- Santana, M. S., Chaves, E. M. M. (2009). Atividade Física e Bem-Estar na Velhice. *Rev Salud Pública*, 11:225-236.

- Silva, N. L., Farinatti, P. T. V. (2007). Influence of counter-resistance training variables on elderly muscular strength: a systematic review with emphasis on dose/response relationships. *Rev Bras Med do Esporte*, 13(1):51–57. <https://doi.org/10.1590/S1517-86922007000100014>.
- Silva, R. P. M., Gonçalves, A., Silva, C. F., Bortolini, M. J. S., Resende, E. S., Gonçalves, L. C. O., Magalhães-Neto, A. M., Espindola, F. S. (2024). Correlation Between Blood Lactate and Salivary Biomarkers During Exercise in Women with Hypothyroidism Treated With L-Thyroxine. *Phys. Educ. Sport Stud. Res*, 3(1); 57-76. <https://doi.org/10.56003/pessr.v3i1.346>.
- Siri, W. E. (1961). Body composition from fluid spaces and density. In: Brozek J. & Henschel, A. (Eds). *Techniques for measuring body composition*, National Academy of Science. Washington DC; 1961:223-244.
- Souza, L. K., Bortoluzzi, R., Roncada, C., Tiggemann, C. L., Dias, C. P. (2014). Comparação da força e capacidade funcional entre idosos praticantes de musculação , hidroginástica e não praticantes de exercícios físicos. *Rev Bras Geriatr e Gerontol*, 17(3):497–504. <https://doi.org/10.1590/1809-9823.2014.13046>.
- Souza, A. V., Teixeira, R. R., Caixeta, D. C., Silva, A. T. F., Gonçalves, L. C. O., Giolo, J. S., Vilela, D. D., Peixoto, L. G., Magalhães-Neto, A. M., Maia, Y. C. P., Sabino-Silva, R., Puga, G. M., Espindola, F. S. (2024). Salivary spectral signature using ATR-FTIR spectroscopy in different exercise protocols. *Spectrochim Acta A Mol Biomol Spectrosc*, 320:124599. <https://doi.org/10.1016/j.saa.2024.124599>.
- Stefanick, M. L., Mackey, S., Sheehan, M., Ellsworth, N., Haskell, W. L., Wood, P. D. (1998). Effects of Diet and Exercise in Men and Postmenopausal Women with Low Levels of HDL Cholesterol and High Levels of LDL Cholesterol. *N Engl J Med*, 339(1):12–20. <https://doi.org/10.1056/NEJM199807023390103>.
- Teran-Garcia, M., Rankinen, T., Koza, R., Rao, D. C., Bouchard, C. (2005). Endurance training-induced changes in insulin sensitivity and gene expression. *Am J Physiol Endocrinol Metab*, 288(6):E1168– E1178. <https://doi.org/10.1152/ajpendo.00467.2004>.
- Vale, R. G. S., Barreto, A. C. G., Novaes, J. S., Dantas, E. H. M. (2006). Effect of resistive training on the maximum strenght, flexibility and functional autonomy of elderly woman. *Rev bras cineantropom desempenho hum*, 8(4):52–58.
- Veras, R. (2009). Envelhecimento populacional contemporâneo: demandas, desafios e inovações. *Rev Saude Publica*, 43(3):548–554. <https://doi.org/10.1590/S0034-89102009005000025>.
- World Health Organization. (2009). *Global health risks: mortality and burden of disease attributable to selected major risks*, Geneva: WHO; 2009:1-62.
- World Health Organization. (2010). *Global recommendations on physical activity for health*, Geneva: WHO; 2010:1-58.
- World Health Organization. (2014). *Global status report on noncommunicable diseases 2014*, Geneva: WHO; 2014:1-280.