Universidade de Lisboa
Faculdade de Motricidade Humana

Design and implementation of an exercise intervention focused on postural stability, and evaluation of its impact on gait pattern and functional fitness of the older population

Maria de Fátima Florentino Gonçalves Ramalho

Orientadores: Professora Doutora Maria Filomena Araújo da Costa Cruz Carnide

Professora Doutora Rita Alexandra Prior Falhas Santos Rocha

Tese especialmente elaborada para obtenção do grau de Doutor em Motricidade Humana na especialidade de Biomecânica

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List of abbreviations

- BMI – body mass index
- FF – functional fitness
- PA – physical activity
- PP – plantar pressure
- M01 - Mask 1 – Heel
- M02 – Mask 2 - Midfoot
- M03 – Mask 3 - Medial-part of the metatarsals
- M04 - Mask 4 – Big toe
- M05 - Mask 5 – Lesser toes
- M06 - Mask 6 – Lateral-part of the metatarsals
- ADLs - Activities of daily living
- IADLs - Instrumental activities of daily living
- RCTs – Randomized Clinical Trails
- CT – Control Trial
- UT – Uncontrol trial
- DT - Dual Task
- OA – Osteo Arthritis
- CoP - Plantar center of pressure
- MVPA - moderate-to-vigorous PA
- MAAP – More Active Aging Program
- IG - intervention group
- CG - control group
- Borg CR-10 RPE – 10 points Borg Rate of Perceived Exertion
- BW - body weight
- SFT - Senior Fitness Tests
- FAB - Fullerton Advanced Balance Scale
- GRF - Applied local vertical ground reaction force
- TOF - Total force in an anatomical foot area
- PPM and PPm - Maximum and mean applied local pressure
- PTI - Pressure-time integral
- FTI - Force-time integral in an anatomical area
- TFL - Force-time integral timing of foot loading
- IMP - Impulse
- DFL - Deformation of the foot during loading
- CS - 30s chair stand test
- U&G - 8 foot up and go test
- 2min - 2-minute step test
- FAB6 - Stand on one leg test
- FAB7 - Stand on foam with eyes closed test
- FAB4 - Step up and over test
- FAB5 - Tandem walking test
- YPAS - Yale Physical Activity Survey
- NOPP – Non periodized program
- MAAP - EG1 – More Active Aging Program - exercise group 1
- NOPP - EG2 - Non-periodized program - exercise group 2

Sumário

Conceção e implementação de um programa de exercício físico com ênfase na estabilidade postural, e avaliação dos seus efeitos no padrão de marcha e funcionalidade duma população idosa

O processo de envelhecimento conduz ao declínio da funcionalidade e contribui para a prevalência e aumento da incidência de quedas na população idosa. Este fator constitui-se como um importante problema de saúde pública, relevante para o atual contexto social Europeu. O exercício físico apresenta-se como um fator determinante na prevenção e redução de quedas na população idosa, através da melhoria das capacidades físicas e pela alteração do padrão de marcha, contribuindo para a adoção de estratégias de resposta às circunstâncias relacionadas com a ocorrência de quedas.

Os objetivos do presente estudo focaram-se na conceção e avaliação dos efeitos de um programa de exercício de longa duração, centrado na estabilidade postural e na melhoria da eficiência mecânica da marcha que, por sua vez, possa contribuir para o aumento da funcionalidade e autonomia da pessoa idosa.

Os objetivos específicos da presente tese foram:

1 - Desenvolver uma revisão narrativa de forma a analisar as evidências mais recentes sobre os seguintes tópicos: (1) importância da funcionalidade da marcha no processo de envelhecimento ativo; (2) que parâmetros biomecânicos da marcha podem ser utilizados como expressão de funcionalidade da população idosa; e (3) se as intervenções com atividade física têm um efeito positivo nos parâmetros biomecânicos da marcha;

2 - Desenvolver um protocolo de estudo de intervenção com base num programa de exercício para a comunidade, que objetive a melhoria dos parâmetros da marcha e da funcionalidade de uma população idosa;

3 - Desenvolver um estudo quasi-experimental de forma a avaliar os efeitos de uma intervenção periodizada com base num programa de exercício para a comunidade, na melhoria dos parâmetros da marcha e da funcionalidade de uma população idosa, por comparação a uma intervenção não-periodizada;

Decorrente da revisão da literatura e construção de protocolo de intervenção, foi aplicada uma intervenção com base num programa de exercício físico. Foram utilizadas metodologias específicas de avaliação biomecânica do padrão de marcha, da ocorrência de quedas, do estado de saúde, e da aptidão funcional desta população.

Destacamos a importância social da intervenção que se pretende implementar na comunidade.

Palavras-chave*: população idosa, exercício, condição física, funcionalidade, marcha, pressão plantar.*

Summary

Design and implementation of an exercise intervention focused on postural stability, and evaluation of its impact on gait pattern and functional fitness of an older population.

The aging process leads to a decline in functional fitness and hence the increased prevalence of falls in the elderly. This type of event constitutes an important public health issue, relevant in the current European social context. Exercise plays a key role in the prevention and reduction of falls by improving physical capabilities and the change in gait pattern, contributing to the adoption of strategies responsive to the circumstances underlying their occurrence.

The aim of this research was to design and evaluate the effect of an exercise program, long-term, focused on postural stability and improving the mechanical efficiency of walking, which, in turn, is expected to contribute to an increased functionality and autonomy of the older population.

Thus, the purposes of this thesis were:

1 - To conduct a review in order to investigate the available evidence on the following topics: (1) how important is gait ability in relation to the active aging process; (2) which gait parameters can be used as expression of functionality of older adults, and (3) whether physical activity interventions have a positive effect on gait parameters;

2 - To develop a study protocol regarding a community-based exercise intervention for gait and functional improvement in an older population;

3 - To develop a quasi-experimental study in order to analyze the effects of a community-based periodized exercise intervention on the improvement of gait parameters and functional fitness in an older adults' population when compared with a non-periodized program.

In line with the literature review, a study protocol was built, and an exercise intervention was performed. Specific biomechanical methodologies were used in assessing the gait pattern, fall occurrence, health status, and functional fitness in this population. We highlight the important social role of this community intervention.

Key-words: older population, exercise, physical fitness, functionality, gait, plantar pressure.

1. Introduction

1.1. Rationale for the investigation

The aging process leads to a decline in functional fitness and hence the increased prevalence of falls in the elderly (WHO, 2015). This type of event constitutes an important public health issue, relevant in the current European social context. This is an important public health issue, with significance in the current European social context. Physical exercise presents itself as a determining factor in the prevention and reduction of falls by improving physical capacities and changes in the gait pattern, contributing to the adoption of strategies to respond to the circumstances underlying their occurrence (Sherrington et al., 2019). According to the European project, “Prevention of Falls Network Europe” (ProFaNE), a fall can be defined as “an unexpected event, in which the individual moves to a position of immobility on the ground or to a lower level” (Tromp, Pluijm, Smit, Deeg, Bouter & Lips, 2001). In addition to being both the major cause of hospitalization and the reason why people over 65 have to move to a care home, falls have important negative consequences for the quality of life of the elderly and represent a clinical and a public health problem with social and financial costs (Di Prieto et al., 2019). The high prevalence of osteoporosis at an advanced age, together with the functional decline associated with aging, can transform a small fall into an incapacitating event with unpredictable repercussions (AGS, 2001; Carter, Kannus & Khan, 2001; Daley & Spinks, 2000; Rikli & Jones, 2001). Finding intervention programs which prevent functional decline, gait impairments and falls and reduce the intensity of their consequences add great relevance to this study.

Amongst the recognized risk factors related to falls, postural instability and biomechanical changes in the gait pattern are considered as two of the reasons for this type of adverse event. Locomotion depends on the individual’s ability to effectively integrate both postural control and movements of the upper and lower limbs. Changes in the neuromuscular function, namely a decrease in strength and power in the lower limbs, as well as a decrease in the ability of the visual, vestibular, and somatosensory systems affects the postural stability of the elderly, not only in the bipedal position (bipedal and unipedal), but also in the response to unexpected changes of balance or the voluntary overcoming / climbing of obstacles / steps (Cruz-Jimenez, 2017; Dorfman et al, 2014; Busch et al, 2015).

Moreover, gait is no longer considered merely a simple motor activity but rather an activity that requires executive function and attention, as well as judgment of external and internal cues (Amboni et al., 2013). The ability to walk underlies many basic and instrumental or occupational functions needed for independence. Changes in gait are associated with functional decline, independence loss, and impaired quality of life (Cruz-Jimenez, 2017).

There is evidence that gait speed is a clinical marker and an important measure of functional capacity among the elderly (Busch et al., 2015). Lower walking speed is associated with age, education, but especially with modifiable factors such as impairment of instrumental activities daily living (IADLs), physical inactivity and cardiovascular disease, reinforcing how important it is for the elderly to remain active and healthy.

Exercise plays a key role in the prevention and reduction of falls by improving physical capabilities and the change in gait pattern, contributing to the adoption of strategies responsive to the circumstances underlying their occurrence (Di Prieto et al, 2019).

Participation in appropriate exercise programs related to the control of the risk factors can help prevent falls and reduce their consequences, both in terms of the severity of the injuries and more or less permanent changes in the lifestyle of the elderly (AGS, 2001; Rubenstein & Josephson, 2002; Simoneau et al., 1991). However, evidence of the isolated role of exercise is inconsistent (AGS, 2001; Rubenstein & Josephson, 2002; Simoneau et al., 1991). The scarcity of data regarding the specific characteristics of the applied activity, as well as the influence of other variables namely visual impairment due to age (Judge, King, Whipple, Clive & Wolfson, 1995; Rose, 2003), and levels of physical activity, makes the interpretation of the data particularly complex.

1.2. General research questions

Several studies have identified physical activity programs that have shown positive effects in preventing falls. It was found that the programs that showed greater efficacy involved exercises with progressive alteration of balance, using body weight and reduced support of the upper limbs. Equally, it is known that aerobic and flexibility training may prove beneficial when associated with balance exercises, as well as the specific conditioning of the following functional components: strength and power in the lower limbs, balance and postural stability, coordination and reaction time (Sherrington et al., 2019).

The relevance of this study is based on the fact that there is a need for further research in intervention programs, closer to the functional reality of the elderly with the purpose of defining the type of exercise, its frequency, its duration and intensity, as well as a training periodization methodology showing a positive impact on postural control, balance and locomotion of the elderly population and contributing to the prevention of functional decline, gait impairments and falls in elderly population.

1.3. Purposes of the thesis

The aim of this research was to design and evaluate the effect of an exercise program, long-term, focused on postural stability and improving the mechanical efficiency of gait, which, in turn, is expected to contribute to an increased functionality and autonomy of the older population.

The following hypotheses were raised:

1. A long-term periodized exercise intervention focused on postural stability will be effective for the improvement of the mechanical efficiency of gait and functional fitness parameters of older participants;
2. This exercise intervention will be more effective than a usual exercise program.

Thus, the purposes of this thesis were:

1 - To conduct a review in order to investigate the available evidence on the following topics: (1) how important is gait ability in relation to the active aging process; (2) which gait parameters can be used as expression of functionality of older adults, and (3) whether physical activity interventions have a positive effect on gait parameters;

2 - To develop a study protocol regarding a community-based exercise intervention for gait and functional improvement in an older population;

3 - To develop a quasi-experimental study in order to analyze the effects of a community-based periodized exercise intervention on the improvement of gait parameters and functional fitness in an older adults' population when compared with a non-periodized program.

The study was approved by the Ethics Committee of Faculty of Human Kinetics, University of Lisbon - CEFMH Approval Number: 29/2013

This thesis embraces a compilation of five chapters including three papers (one submitted and two published), as shown in figure 1.

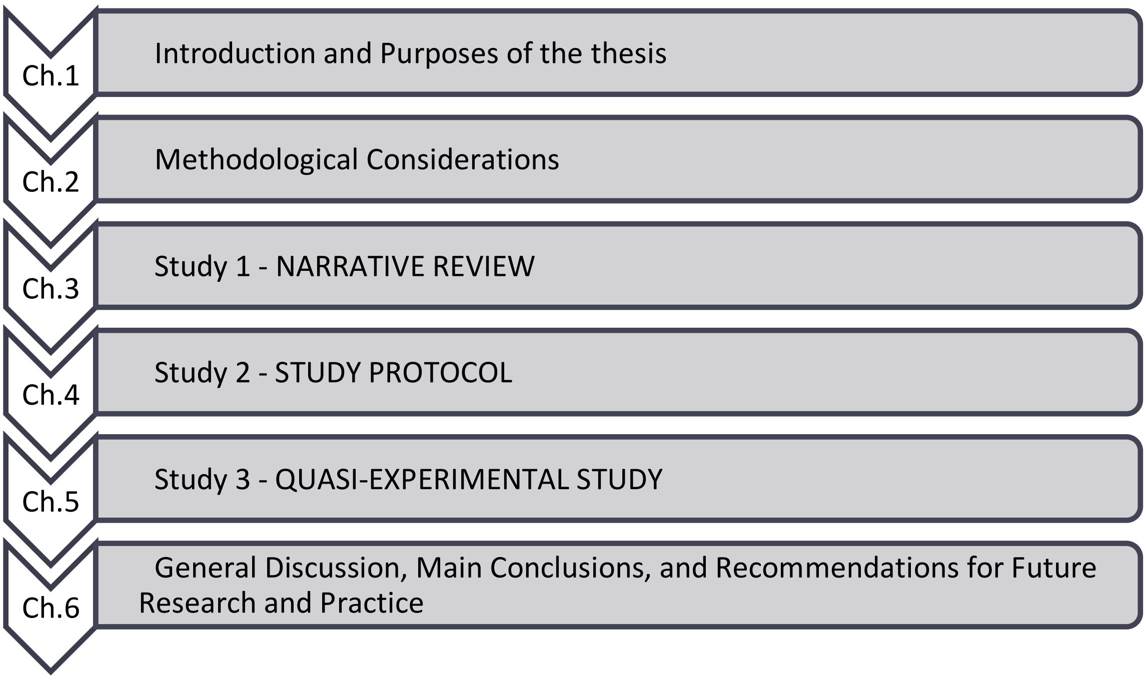

Figure 1. Thesis overview

1.4. References

ACSM (2009). ACSM Position Stand on Exercise and Physical Activity for Older Adults. Medicine and Science in Sports and Exercise (30), 1510-1530.

AGS (2001). Guideline for the prevention of falls in older persons. American Geriatrics Society, British Geriatrics Society, and American Academy of Orthopaedic Surgeons Panel on Falls Prevention. J Am Geriatr Soc, 49(5), 664-672.

Amboni, M., Barone, P., & Hausdorff, J. M. (2013). Cognitive Contributions to Gait and Falls: Evidence and Implications. Movement Disorders, 28(11), 1520-1533. doi:10.1002/mds.25674

Busch, T.d.A., Duarte, Y.A., Pires Nunes, D. et al. (2015). Factors associated with lower gait speed among the elderly living in a developing country: a cross-sectional population-based study. BMC Geriatr 15, 35. https://doi.org/10.1186/s12877-015-0031-2

Carter, Kannus, & Khan. (2001). Exercise in the prevention of falls in older people: a systematic literature review examining the rationale and the evidence. Sports Med, 31(6), 427-438.

Cruz-Jimenez M (2017). Normal Changes in Gait and Mobility Problems in the Elderly. Phys Med Rehabil Clin N Am.;28(4):713-725. doi: 10.1016/j.pmr.2017.06.005

Daley, & Spinks. (2000). Exercise,Mobility and Aging. Sports Medicine, 29.

Dipietro L, Campbell WW, Buchner DM, Erickson KI, Powell KE, Bloodgood B, Hughes T, Day KR, Piercy KL, Vaux-Bjerke A, Olson RD; 2018 Physical Activity Guidelines Advisory Committee. (2019). Physical Activity, Injurious Falls, and Physical Function in Aging: An Umbrella Review. Med Sci Sports Exerc. ;51(6):1303-1313. doi: 10.1249/MSS.0000000000001942.

Dipietro L, Caspersen CJ, Ostfeld AM, Nadel ER.(1993). A survey for assessing physical activity among older adults. Med Sci Sports Exerc., May;25(5):628-42.

Dorfman, M., Herman, T., Brozgol, M., Shema, S., Weiss, A., Hausdorff, J. M., & Mirelman, A. (2014). Dual-Task Training on a Treadmill to Improve Gait and Cognitive Function in Elderly Idiopathic Fallers. Journal of Neurologic Physical Therapy, 38(4), 246-253. doi:10.1097/Npt.0000000000000057

Gillespie, L. D., Robertson, M. C., Gillespie, W. J., Sherrington, C., Gates, S., Clemson, L. M., & Lamb, S. E. (2012). Interventions for preventing falls in older people living in the community. Cochrane Database Syst Rev(9), Cd007146. doi:10.1002/14651858.CD007146.pub3

Guimaraes, & Isaacs. (1980). Characteristics of the gait in old people who fall. Int Rehab Med(2), 177-180.

Judge, King, Whipple, Clive, & Wolfson. (1995). Dynamic balance in older persons: effects of reduced visual and proprioceptive input. J Gerontol A Biol Sci Med Sci, 50(5), M263-270.

Lord, Sherrington, Menz & Close (2007). Falls in Older People.Cambridge Cambridge: University Press,

Lord, Ward, & Williams. (1995). The effect of a 12-month exercise trial on balance, strength, and falls in older women: a randomized control trial. J Am Geriatr Soc, 43, 1198-1206.

National Center for Injury Prevention and Control, (2008). Preventing Falls: How to Develop Community-based Fall Prevention Programs for Older Adults. Atlanta, Georgia,

Province, Hadley, Hornbrook, Lipsitz, Miller, Mulrow, et al. (1995). The effects of exercise on falls in elderly patients. A preplanned meta-analysis of the FICSIT Trials. Frailty and Injuries: Cooperative Studies of Intervention Techniques. Jama, 273(17), 1341-1347.

Rikli, & Jones. (2001). Senior Fitness Test Manual. Champaign: Human Kinetics.

Rose, D (2003). Fall Proof: a comprehensive balance and mobility training program. Champaign: Human Kinetics

Rubenstein, & Josephson. (2002). The epidemiology of falls and syncope. Clin Geriatr Med, 18(2), 141-158.

Simoneau, Cavanagh, Ulbrecht, Leibowitz, & Tirel. (1991). The influence of visual factors on falls-related kinematic variables during stair descent by older women. Journal of Gerontology: Medical Sciences, 46, M118-M195.

Sturnieks D. L., Finch C. F., Close J. C.T, Tiedemann A., Lord S. R., Pascoe D. A. (2010). Exercise for falls prevention in older people: Assessing the knowledge of exercise science students", Journal of Science and Medicine in Sport, 13 59–64

Tinetti, & Speechley. (1989). Prevention of falls among the elderly. N Engl J Med, 320(16), 1055-1059.

Tinetti. (1986). Performance-oriented assessment of mobility problems in elderly patients. J Am Geriatr Soc, 34(2), 119-126.

Tromp, Pluijm, Smit, Deeg, Bouter, & Lips. (2001). Fall-risk screening test: a prospective study on predictors for falls in community-dwelling elderly. J Clin Epidemiol, 54(8), 837-844.

Winter, Patla, Frank, & Walk. (1990). Biomechanical walking pattern changes in the fit ans healthy elderly. Phys Ther, 70(6), 340-348.

World Health Organization (2015). World report on aging and health: World Health Organization. Geneva: WHO

2. Methodological Considerations

2.1. Plantar Pressure Assessment

The feet are the first mean of interaction with involvement during locomotion and represent one of the largest indicators of dependency in humans. Also during locomotion, the foot is the end of the kinematic chain, which assists in the fine adjustments in control of muscle activity that is required to maintain balance (Rosenbaum & Becker, 1997). Regarding the means and methods used in the present work, several methodological definitions are possible to use in order to evaluate the mechanics of a subject during a specific task. According to Elliott (1999) clinical biomechanics also involves research in the areas of gait, neuromuscular control, and movement evaluation in different conditions. The biomechanical methodologies applied here are based on the evaluation of the foot plantar pressure during walking gait before and after exercise-based intervention.

Plantar pressure has been presented as the mean to quantify the amount of pressure done by each part of the foot. As described in **Equation 1**, this quantification is possible by measuring the amount of forces (F) normal to the surface of interest, usually the vertical forces acting on the foot when walking (Jameson et al., 2008; Nigg & Herzog, 2007; Rosenbaum & Becker, 1997; Wallace, White, Augsburger, Shapiro, & Walker, 2018), and measuring the contact area (A) of the foot, with a System International Unit of newtons per square meter (N/m^2).

$$\boldsymbol{P = \frac{F}{A}}$$

Equation 1. Pressure equation.

The area of the foot is usually measured by sensors placed in different kind of systems, such as plantar pressure platforms or insoles. Because our task is the walking gait, the preferable system to collect data is the platform, which is built from flat, rigid array of pressure sensors arranged in a matrix configuration and embedded in the floor to allow normal gait (Razak, Zayegh, Begg, & Wahab, 2012). This system also allows the sample to walk in barefoot and without any constraints of shoes and socks. The plantar pressure platform used was emed® n50 (novel®, Germany). This platform has a dimension of 610x323x15.5mm with 6.080 sensors, a resolution of 4 sensors/cm^2, and frequency capture of 50Hz. In Table 1 the main characteristics of platform are shown (novel, 2019).

Table 1. Technical data for the emed®-n50 platform (novel, 2019).

Characteristic	Data
Dimensions (mm)	700 x 403 x 15.5 (18)
Sensor area (mm)	475 x 320
Number of sensors	6.080
Resolution (sensors/cm^2)	4
Frequency (Hz)	50
Pressure range (kPa)	10 – 1.270
Pressure threshold (kPa)	10
Accuracy (% ZAS)	± 5
Hysteresis (%)	< 3
Temperature range (°C)	15 - 40
Max. total force (N)	193.000
Cross talk (db)	- 40

This platform is build based on capacitive sensors, which have been used in the last 20 years because of its advantages such as high-pressure sensitivity and low power consumption (Nie, Bao, & Huang, 2000). The basic principle of capacitive pressure sensors is that it is possible to compute the capacitance of the pressure-based deformation between two parallel plates (Equation 2).

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d}$$

Equation 2. Equation of Capacitance.

Where *C* is the capacitance, ε_0 is 8.854x10^{-12}, ε_r is the relative permittivity of the dielectric medium, *A* is the effective surface area of the parallel plates, and *d* is the separation distance between the parallel plates (Nie et al., 2000).

Usually, during sensor fabrication, all independent variables of this equation are made constant, with exception to distance between parallel plates, changing the variation of capacitance, according to variation of that distance, which can be converted to electric output by the detection circuits (**Figure 2**). This type of fabrication is named as space-variant capacitive sensors (Nie, Bao, & Huang, 2000). The capacitance responds almost in a linear way to pressure, as pointed by Ettouhami, Zahid, and Elbelkacemi (2004).

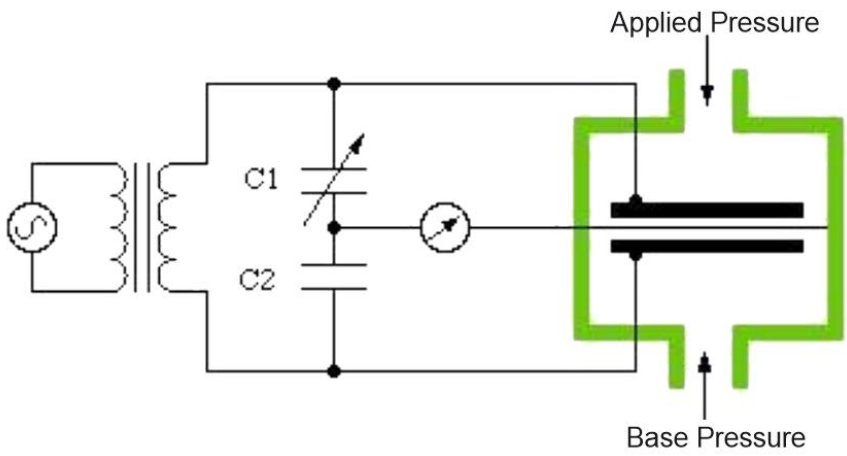

Figure 2. Capacitor sensor schematics (adapted from (Razak, Zayegh, Begg, & Wahab, 2012)).

Although the construction of sensors and systems are valid and reliable for biomechanical data collection (Giacomozzi, 2010; Gurney, Kersting, & Rosenbaum, 2008), the collections on plantar pressure platforms have some associated precautions. The first precaution to consider is the need of the foot to fully support in the platform, preferably in the center of it. The second precaution is the necessity to the platform be hidden or dissimulated, in order to do not disturb the normal gait pattern. The third limitation is about the surrounding area, which should be clean from any objects and to have enough space allowing to achieve a comfortable and self-selected pace. If the collections are performed in new environments for the subjects, it is necessary to allow a familiarization with the task in that space to ensure a natural gait (Razak et al., 2012).

The information added from plantar pressure distribution can be used for a variety of purposes, including modifying footwear, foot orthoses, advising limitations on carrying loads and exercise programs, and therefore in research (Orlin & McPoil, 2000; Zulkifli & Loh, 2018). In fact, plantar pressure provides information about the influence that different movements or activities have on the feet and/or lower limbs. This shows the relevance that these instruments have in the area of exercise and health, not only allowing the above, but also in the description that a particular problem / illness / disability or exercise program has on the foot and lower extremities. For these purposes, is usual to analyze the plantar pressure distributions by region of the foot, also known as masks. The quantity of foot masks in analysis have not a well-defined criterion, but it usually depends on the purpose of the study and the kind of observation and detail that researchers want to put into the study. The analysis of the foot by different regions depends on the details of the analysis or the ability to detect frailties. In this study, a division of the foot into six masks was used (Figure 3), allowing to evaluate the application of the exercise program on the:

- Heel (Mask 1 – M01)
- Midfoot (Mask 2 – M02)
- Medial-part of the metatarsals (Mask 3 – M03)
- Big toe (Mask 4 – M04)
- Lesser toes (Mask 5 – M05)
- Lateral-part of the metatarsals (Mask 6 – M06)

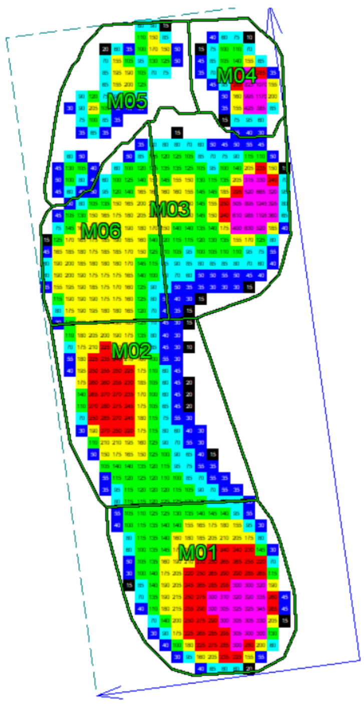

Figure 3. Schematics of foot division by masks.

During collection, the sensors are activated when pressure is applied and depending of pressure magnitude different colors are visualized for better assessment (Figure 4). Each mask is created automatically through *Automask* software from novel®, however during this creation, each mask is visually checked and corrected if necessary.

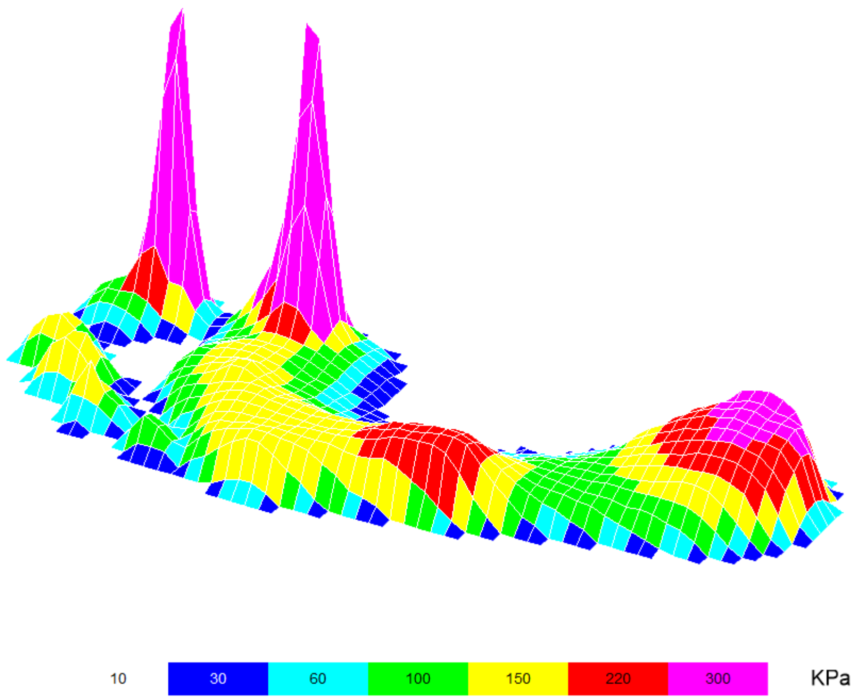

Figure 4. Plantar pressure visualization, with magnitudes and associated colors.

In Table 2, are described the plantar pressure related variables (Novel, 2013).

Table 2. Plantar Pressure related variables and their description.

Variable Name	Description	Units (SI)
Maximum force	Corresponds to maximum value of force occurred in each mask	Newtons
Instant of maximum force	Instant of time in which the highest value of force occurs	milliseconds % of single foot stance
Force-time integrals	Is calculated as the sum of products of peak forces in each frame and the duration of one frame	Newton.second (N.s)
Mean Force	Corresponds to mean forces between trials for each mask or all foot	Newtons
Maximum pressure	Highest value of pressure within a mask	Kilopascal (kPa)
Instant of peak pressure	Instant of time in which the highest value of pressure occurs	milliseconds % of single foot stance
Pressure-time integrals	Is calculated as the sum of products of peak pressure in each frame and the duration of one frame	Kilopascal.second (kPa.s)
Mean pressure	Mean of maximum pressure among each file	Kilopascal (kPa)
Mean Area	Corresponds to mean area between trials for each mask or all foot	cm^2
Contact areas	Area of activated sensors	cm^2
Contact time	Total time of foot / mask contact with the ground	milliseconds
Contact Relative time	Ratio of mask contact time to total contact time	%

For each mask and for all the foot, the maximum value, the instant of maximum value, the time integrals, and the mean value are calculated, both for pressure and for reaction forces. In addition, it was also calculated the contact areas, the mean area, the total time of contact of the foot with the ground and the relative contact time of each mask compared to the total time.

2.2. References

Carroll, M., Parmar, P., Dalbeth, N., Boocock, M., & Rome, K. (2015). Gait characteristics associated with the foot and ankle in inflammatory arthritis: a systematic review and meta-analysis. BMC Musculoskelet Disord, 16, 134. doi:10.1186/s12891-015-0596-0

Doi, T., Shimada, H., Makizako, H., Tsutsumimoto, K., Uemura, K., Anan, Y., & Suzuki, T. (2014). Cognitive function and gait speed under normal and dual-task walking among older adults with mild cognitive impairment. Bmc Neurology, 14. doi:Artn 6710.1186/1471-2377-14-67

Dumurgier, J., Elbaz, A., Ducimetiere, P., Tavernier, B., Alperovitch, A., & Tzourio, C. (2009). Slow walking speed and cardiovascular death in well functioning older adults: prospective cohort study. BMJ, 339, b4460. doi:10.1136/bmj.b4460

Elbaz, A., Sabia, S., Brunner, E., Shipley, M., Marmot, M., Kivimaki, M., & Singh-Manoux, A. (2013). Association of walking speed in late midlife with mortality: results from the Whitehall II cohort study. Age (Dordr), 35(3), 943-952. doi:10.1007/s11357-012-9387-9

Elliott, B. (1999). Biomechanics: An integral part of sport science and sport medicine. Journal of Science and Medicine in Sport, 2(4), 299-310. doi:10.1016/S1440-2440(99)80003-6

Ettouhami, A., Zahid, N., & Elbelkacemi, M. (2004). A novel capacitive pressure sensor structure with high sensitivity and quasi-linear response. Comptes Rendus Mecanique, 332(2), 141-146. doi:https://doi.org/10.1016/j.crme.2003.10.001

Fawzy, O. A., Arafa, A. I., El Wakeel, M. A., & Abdul Kareem, S. H. (2014). Plantar pressure as a risk assessment tool for diabetic foot ulceration in egyptian patients with diabetes. Clin Med Insights Endocrinol Diabetes, 7, 31-39. doi:10.4137/CMED.S17088

Garcia-Pinillos, F., Cozar-Barba, M., Munoz-Jimenez, M., Soto-Hermoso, V., & Latorre-Roman, P. (2016). Gait speed in older people: an easy test for detecting cognitive impairment, functional independence, and health state. Psychogeriatrics, 16(3), 165-171. doi:10.1111/psyg.12133

Giacomozzi, C. (2010). Appropriateness of plantar pressure measurement devices: a comparative technical assessment. Gait & Posture, 32(1), 141-144. doi:10.1016/j.gaitpost.2010.03.014

Gurney, J. K., Kersting, U. G., & Rosenbaum, D. (2008). Between-day reliability of repeated plantar pressure distribution measurements in a normal population. Gait & Posture, 27(4), 706-709. doi:10.1016/j.gaitpost.2007.07.002

Hardy, S. E., Perera, S., Roumani, Y. F., Chandler, J. M., & Studenski, S. A. (2007). Improvement in usual gait speed predicts better survival in older adults. Journal of the American Geriatrics Society, 55(11), 1727-1734. doi:10.1111/j.1532-5415.2007.01413.x

Hazari, A., Maiya, A. G., Shivashankara, K. N., Agouris, I., Monteiro, A., Jadhav, R., . . . Mayya, S. S. (2016). Kinetics and kinematics of diabetic foot in type 2 diabetes mellitus with and without peripheral neuropathy: a systematic review and meta-analysis. Springerplus, 5(1), 1819. doi:10.1186/s40064-016-3405-9

Jameson, E. G., Davids, J. R., Anderson, J. P., Davis, R. B., Blackhurst, D. W., & Christopher, L. M. (2008). Dynamic pedobarography for children - Use of the center of pressure progression. Journal of Pediatric Orthopaedics, 28(2), 254-258. doi:DOI 10.1097/BPO.0b013e318164ee6e

McKay, M. J., Baldwin, J. N., Ferreira, P., Simic, M., Vanicek, N., Wojciechowski, E., . . . Norms Project, C. (2017). Spatiotemporal and plantar pressure patterns of 1000 healthy individuals aged 3-101 years. Gait & Posture, 58, 78-87. doi:10.1016/j.gaitpost.2017.07.004

Mielke, M. M., Roberts, R. O., Savica, R., Cha, R., Drubach, D. I., Christianson, T., . . . Petersen, R. C. (2013). Assessing the temporal relationship between cognition and gait: slow gait predicts cognitive decline in the Mayo Clinic Study of Aging. J Gerontol A Biol Sci Med Sci, 68(8), 929-937. doi:10.1093/gerona/gls256

Nakajima, K., Anzai, E., Iwakami, Y., Ino, S., Yamashita, K., & Ohta, Y. (2014). Measuring gait pattern in elderly individuals by using a plantar pressure measurement device. Technology and Health Care, 22(6), 805-815. doi:10.3233/Thc-140856

Nie, M., Bao, H., & Huang, Q.-A. (2000). Capacitive Pressure Sensors. In J. G. Webster (Ed.), Wiley Encyclopedia of Electrical and Electronics Engineering: Wiley Online Library.

Nigg, B. M., & Herzog, W. (2007). Biomechanics of the musculo-skeletal system (3rd ed.). New Jersey: John Wiley & Sons.

Novel. (2013). novel scientic medical projects manual. In novel (Ed.).

Novel. (2019). emed Pedography Systems. In n. gmbh (Ed.). Germany: novel.

Orlin, M. N., & McPoil, T. G. (2000). Plantar Pressure Assessment. Physical Therapy, 80(4), 399-409. doi:10.1093/ptj/80.4.399 %J Physical Therapy

Raspovic, A. (2013). Gait characteristics of people with diabetes-related peripheral neuropathy, with and without a history of ulceration. Gait & Posture, 38(4), 723-728. doi:10.1016/j.gaitpost.2013.03.009

Razak, A. H. A., Zayegh, A., Begg, R. K., & Wahab, Y. (2012). Foot Plantar Pressure Measurement System: A Review. Sensors, 12(7), 9884-9912. doi:10.3390/s120709884

Rosenbaum, D., & Becker, H. P. (1997). Plantar pressure distribution measurements. Technical background and clinical applications. Foot and Ankle Surgery, 3(1), 1-14. doi:https://doi.org/10.1046/j.1460-9584.1997.00043.x

Wallace, J., White, H., Augsburger, S., Shapiro, R., & Walker, J. (2018). Foot pressure analysis using the emed® in typically developing children and adolescents: A summary of current techniques and typically developing cohort data for comparison with pathology. The Foot, 37, 28-37. doi:https://doi.org/10.1016/j.foot.2018.04.007

Wonneberger, M., & Schmidt, S. (2015). Changes of gait parameters following long-term aerobic endurance exercise in mildly disabled multiple sclerosis patients: an exploratory study. European Journal of Physical and Rehabilitation Medicine, 51(6), 755-762.

Zulkifli, S. S., & Loh, W. P. (2018). A state-of-the-art review of foot pressure. Foot and Ankle Surgery. doi:https://doi.org/10.1016/j.fas.2018.12.005

3. A Comprehensive Review on the Interaction Between Gait and Functional Capacity in Older Adults[1]

3.1. Abstract

Background: Gait is a basic pattern of locomotion and walking an easy and readily inexpensive way of exercise in older adults. The aims were to investigate: (1) the importance of gait ability on the active aging process; (2) the gait parameters that can be used as expression of the functionality of older adults; and (3) the effects induced by physical activity on gait parameters. *Methods*: Review studies and original articles using experimental design focusing on older adults' gait biomechanics were searched in PubMed and Scopus and analyzed. *Findings*: Although inconsistent, a relationship between gait and functionality in older adults was examined. Aging is frequently associated with alterations in foot characteristics, contributing to altered plantar loading patterns during gait. Furthermore, the lack of autonomy and the potential of falling may have significant public health implications due to the negative impact on older people's quality of life. *Interpretation*: The association between gait parameters and functionality in older adults is weakened by the few available intervention studies that examine the effects of exercise and physical activity programs on older adults' functionality. Finally, some suggestions for future research were proposed.

Key words: plantar pressure, functional capacity, gait patterns, exercise, elderly

[1] Submitted as:
Ramalho F, Santos-Rocha R, Branco M, Morouço P, Carnide F. (2020). A Comprehensive Review on the Interaction Between Gait and Functional Capacity in Older Adults.

3.2. Introduction

Walking is a complex motor task automatically performed by healthy adults. The aging process increases the demand for locomotor tasks to maintain autonomy and independence in daily life. Thus, walking is often no longer performed automatically by the elderly since older adults require more attention to motor control during walking than younger adults (Bridenbaugh & Kressig, 2011). Further, aging increases the risk of chronic diseases like diabetes and arthritis, falls, fractures, and other neurological injuries, leading to severe gait impairments (Shumway-Cook et al., 2009).

Maintaining functional status is an essential part of active aging and reducing age-related morbidity; it facilitates independent living, improves the quality of life, and reduces health care costs (Chodzko-Zajko et al., 2009). Accordingly, research has stated those age-related changes in spatiotemporal gait parameters. It is consistent that older adults walk more slowly, take shorter steps, and spend more time in double limb support (Cruz-Jimenez, 2017; Krishnan et al., 2018). These features promote the inexistence of a "normal gait" in older adults (Salzman et al., 2010), with aging being associated with changes in foot characteristics that contribute to modulate plantar loading patterns. These changes are expressed by a lower magnitude of forces and pressures under the heel (-13% to 16%), metatarsophalangeal joints (-11% to 16%), and hallux (-19% to 25%), but more significant relative contact time under the heel (+21%), midfoot (+14%) and metatarsophalangeal joints (+5% to 8%) in older participants when compared with younger (Scott et al., 2007).

Gait analysis is increasingly being used to characterize dysfunction of the lower limb and foot in people with several clinical conditions and geriatric syndromes (Brown et al., 2016; Carroll et al., 2015; Ritt, Jager, et al., 2017; Ritt, Ritt, et al., 2017; Schwenk et al., 2014; Wonneberger & Schmidt, 2015). However, the studies that support these results are focused on subclinical populations. Other gait parameters, such as the ten spatiotemporal variables addressed by Ritt, Jager, et al. (2017), most accurately predict 1-year mortality (Ritt, Ritt, et al., 2017). Fortunately, the equipment and methodology used for gait analysis have witnessed substantial developments in recent years. Therefore, reviewing literature related to gait parameters as a functional expression in older adults can provide gaps in the existing literature and help determine future research.

3.3. Objectives

The focus of this review was on the close interaction between gait and functional capacity in older adults. It intends to offer an overview of experimental studies summarizing the literature quantifying biomechanical characteristics (temporal-spatial, kinematic, and kinetics) of gait in older adults and using these parameters as potential identification of risk of gait impairment and other severe outcomes. Furthermore, the following issues were addressed: 1) the importance of gait ability on the active aging process; 2) the usefulness of gait parameters to be used as an expression of functional capacity; and 3) the effects of physical activity and exercise interventions on gait parameters.

3.4. Methods

A comprehensive review was performed; due to (i) the diversity of biomechanical data obtained by different study designs, (iii) and the low number of original research examining the gait patterns in the elderly. A literature search was undertaken in March 2019, using PubMed and Scopus as search engines, to identify systematic reviews and experimental studies published in the English language. In PubMed the filters "humans", "older adults", "since 2000", and "abstract" were used. The following primary search terms were entered: "gait" was combined (using AND) with "biomechanics", "kinematics", "kinetics", and "foot pressure", and searched. Review studies and studies using an experimental design focusing on gait biomechanics of older adults were selected. Additionally, reference lists from identified literature were manually searched for completeness. Papers meeting the inclusion criteria were then manually screened to confirm the content related to the gait patterns in the elderly, specifically. Published abstracts, conference proceedings, dissertation materials were not included in this review. From the pool of 464 potential papers, the criteria used to filter for suitability to be included in the review were the subtopics of each of the questions raised as shown in Figure 5, thus, 410 papers were excluded.

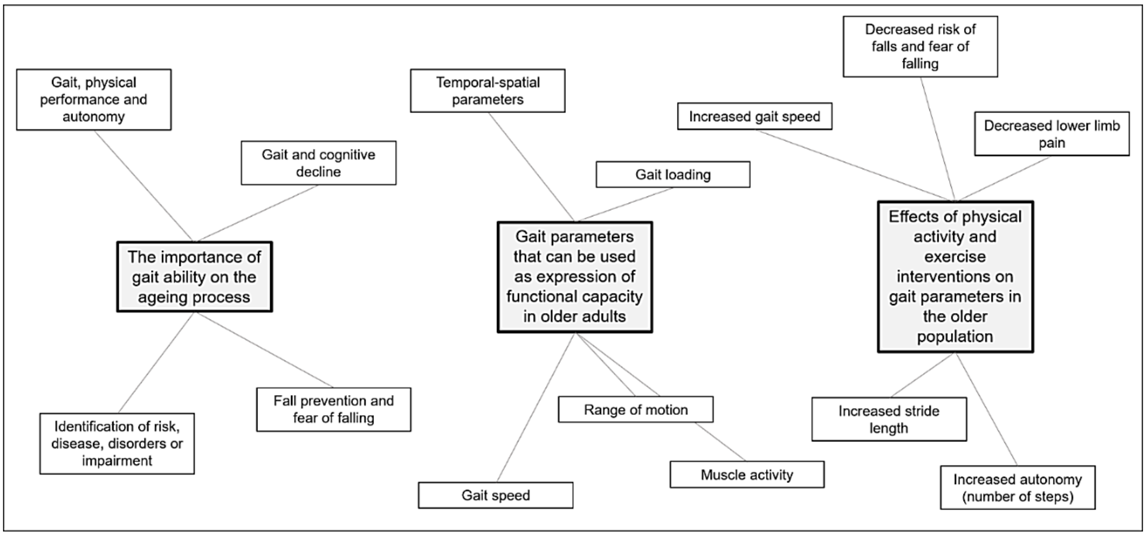

Figure 5. Infographics of the narrative review on gait parameters as expression of functional capacity in older adults.

3.5. The importance of gait ability on the aging process

Activities of daily living (ADLs) require the ability to dual-task, using cognitive resources while walking to negotiate complex environmental conditions (Dorfman et al., 2014). Gait is no longer considered merely a simple motor activity but rather an activity that requires executive function and attention, as well as judgment of external and internal cues (Amboni et al., 2013). The ability to walk underlies many essential and instrumental or occupational functions needed for independence. Changes in gait are associated with functional decline, independence loss, and impaired quality of life (Cruz-Jimenez, 2017). Moreover, these additional cognitive demands often lead to reduced gait quality that increases the risk of falls in older adults (Dorfman et al., 2014). Busch et al. (2015) concluded that gait speed is a clinical marker and an important measure of functional capacity among the elderly. Their findings suggest that lower walking speed is associated with age, education, but especially with modifiable factors such as impairment of instrumental activities of daily living, physical inactivity, and cardiovascular disease, reinforcing how important it is for the elderly to remain active and healthy. A recent study reported the concerning results of 403 community-dwelling older adults' functional ability (Jonkman et al., 2018). The subjects were followed for 9 years, with the majority reporting no functional decline at baseline. However, higher gait speed showed a decreased risk of functional limitations, particularly in males. The final model for males further included predictor's fear of falling and alcohol intake. In the female' model, the higher gait speed interacted with other predictors such as age, living alone, economic satisfaction, balance, physical activity, body mass index, and cardiovascular disease. Interestingly, there are three distinct trajectories of functional decline, differing between males and females, except for gait speed. Besides, these authors stated that the identification of people at risk is the basis for targeting interventions.

With the aging process, physical and cognitive functions become impaired (Garcia-Pinillos et al., 2016). Increasing evidence from clinical practice, epidemiological studies, and randomized clinical trials show that gait and cognition are interrelated in older adults (Montero-Odasso et al., 2012). Likewise, gait ability and cognitive function are complementary during both normal walking and dual-task walking, and gait ability is, thus, adversely affected by cognitive impairment in both conditions (Doi et al., 2014).

Impairments in gait and cognition are prevalent in older adults (Bridenbaugh & Kressig, 2014); gait impairments have an increased risk of developing cognitive impairments. These authors suggested that quantitative gait analysis can provide early detection of gait and cognitive impairments and other adverse outcomes (e.g., falls). Also, it would help to distinguish dementia subtypes in the early stages of the diseases. For instance, Garcia-Pinillos et al. (2016) analyzed the association between physical and cognitive functions in older people and the most appropriate physical test to assess cognitive impairment, functional independence, comorbidity, and perceived health in this population. The authors showed that gait speed is a significant predictor of functional capacity (physical and cognitive function) in adults over 65. Therefore, evidence has been discussed so that impairments in specific cognitive domains might undermine gait and physical performance in the elderly (Bruce-Keller et al., 2012). However, the existence and magnitude of the relationship between gait and cognition are weakened by the few available *intervention* studies that examined the effects of walking on cognition in patients with (preclinical) dementia.

Gait assessment may open a window for understanding the cognitive function and dysfunction and fall risk in older people's clinical practice. An estimated prevalence of 30-40% of older adults over the age of 65 will fall at least once a year, leading to moderate to severe injuries, fear of falling, loss of independence, and death in a third of those patients (Ambrose et al., 2015; Montero-Odasso et al., 2012). If this is the case, a deeper understanding of factors interaction is mandatory. Using a multifactorial approach when assessing the risk of falling, not only focusing on cognitive-behavioral aspects but also on promoting physical activity, when planning an intervention aiming at fall prevention within the older population is paramount (Moniz-Pereira et al., 2013).

On the one hand, falls are a significant public health problem for older people. Falls are among the leading causes of mortality and morbidity in this population and account for 87% of all fractures in the elderly (Ambrose et al., 2015). Accordingly, gait control deficits may explain why older people with a fear of falling are at higher risk of falling (Ganz et al., 2007), as the variability of walking gait timing increases with age (LaRoche et al., 2014). On the other hand, fear of falling may be a more pervasive and severe problem than falls among the elderly (Higuchi et al., 2004). LaRoche et al. (2014) examined the interaction of age, cognitive function, and gait performance during dual-task walking. The authors concluded that reduced cognitive function makes it difficult for older adults to maintain a regular, rhythmical gait pattern while performing a cognitive task, which may place them at greater risk for falling. Fear of falling in the elderly frequently leads to a decreased quality of life. Moreover, fear of falling is suggested to be associated with changes in gait quality and muscle strength with aging (Toebes et al., 2015). Fear of falling and increased gait variability are both independent markers of gait instability (Ayoubi et al., 2015). Higuchi et al. (2004)suggested that even the frail elderly individuals who walk slowly are not afraid of falling if they have a feasible balance function. The authors concluded that, in low-functioning frail elderly, fear of falling is associated with a combination of balance function and gait speed.

Gait impairments are associated with falls and loss of independence. In an epidemiological study, significant differences were found within gait parameters when stratifying by frailty, multimorbidity, disability, multiple medication use, age (>75 years), and sex, for all temporal-spatial gait parameters (velocity, cadence, time, stride duration, stride length, step width). After stratification by the history of falls, only stride length showed a significant difference between the groups of fallers and non-fallers (Thaler-Kall et al., 2015). Nevertheless, a systematic review (Mortaza et al., 2014) reported that a spatiotemporal analysis of level walking is not sufficient and cannot act as a reliable predictor of falls in elderly individuals due to the heterogeneity of methods used and the number of studies that investigated each parameter. Besides, physical activity seems to play a critical role in this process because a higher level of physical activity leads to better functionality. Physical activity was found to be a protective factor for both episodic and recurrent falls (Moniz-Pereira et al., 2012).

Previous research has stated that age was not a risk factor for either episodic or recurrent falling (Moniz-Pereira et al., 2013). Comparing with episodic falls, recurrent falls were more associated with a higher presence of chronic conditions and less likely to occur due to external factors. Being a woman, being afraid of falling, and having lower functional fitness levels were the determinant factors for episodic and recurrent falls. These assumptions are corroborated by further studies stating that the combination of fear of falling with falls increased stride-to-stride variability of stride time (Ayoubi et al., 2015). Thus, the most consistent predictors of future falls are clinically detected abnormalities of gait or balance. Screening for risk of falling during the clinical examination begins with determining if the patient has fallen in the past year. For patients who have not previously fallen, screening consists of an assessment of gait and balance. Patients who have fallen or who have a gait or balance problem are at higher risk of future falls (Ganz et al., 2007).

From a biomechanical point-of-view, differences occur between fallers and non-fallers. For instance, the formers have a decreased peak pressure values at heel strike and toe-off during walking and an extension of the double support phase (Nakajima et al., 2014). Accordingly, higher plantar pressures (i.e., peak pressure and pressure-time integral) during gait contribute to foot pain and risk of falls (Mickle et al., 2010). Shorter steps, slower walking, increased step width, and prolonged double support in healthy older adults may emerge as a compensatory strategy aimed at improving stability, avoiding falls, or reducing the energetic cost of mobility (Aboutorabi et al., 2016).

Although gait disorders are common in the elderly, the prevalence and overall burden of these disorders in the general community is not well defined (Mahlknecht et al., 2013). Disability in ADLs is an adverse outcome of frailty that places a burden on frail older adults, care providers, and the care system (Vermeulen et al., 2011). Early identification of people at risk of functional decline is essential for delivering targeted preventive interventions (Jonkman et al., 2018). Likewise, it has highlighted the mobility limitations experienced by older people in clinical settings and the need for ongoing rehabilitation to attain enough mobility levels for reintegration in the community (Peel & Kuys, 2013). Gait disorders are common in the general elderly population and are associated with reduced mobility (Mahlknecht et al., 2013). Neurological gait disorders are associated with lower cognitive function, depressed mood, and diminished quality of life. Abnormal gait has been associated with a greater risk for adverse outcomes in older adults, such as disability and falls, which in turn lead to loss of functional independence and death (Aboutorabi et al., 2016). Likewise, habitual walking speed predicts many clinical conditions later in life (Hortobagyi et al., 2015).

A systematic review examined the predictive value of physical frailty indicators on ADL disability in community-dwelling older people (Vermeulen et al., 2011). According to these authors, knowing which physical frailty indicators predict ADLs disability is useful in identifying older adults who might benefit from an intervention that prevents disability or increases functioning in daily life. Slow gait speed and low physical activity/exercise seem to be the most potent predictors, followed by weight loss, lower extremity function, balance, muscle strength, and other indicators. Nevertheless, these findings should be interpreted with caution because the data of the different studies could not be pooled due to large variations in the operationalization of the indicators and ADLs disability across the included studies.

From the outputs mentioned above, it is clear that gait analysis is a useful approach for understanding movement impairments, impacting patient well-being (Brown et al., 2016). Research has been conducted for different conditions, demonstrating its usefulness. For instance, gait analysis in patients with diabetes has led to improvements in health care, including the treatment and prevention of ulceration and development of targeted exercise interventions. Diabetes mellitus patients are at increased risk of developing diabetic foot with peripheral neuropathy, vascular, and musculoskeletal complications (Hazari et al., 2016). Therefore, they are prone to develop frequent foot problems with a relatively high risk of infection, gangrene, and amputation. Also, the altered plantar pressure distribution is an essential etiopathogenic risk factor for developing foot ulcers. A systematic review with meta-analysis demonstrated that the study of foot biomechanics (kinematic and kinetic) in type 2 diabetes mellitus to understand the alterations is crucial (Hazari et al., 2016). However, this and other performed reviews denoted a very high level of heterogeneity among studies (Fernando et al., 2013). Although inconsistent and limited by small sample sizes, it seems that diabetic peripheral neuropathy patient has longer stance time and moderately higher plantar pressures at the rearfoot, midfoot, and forefoot compared to controls.

Different pressure variables have been described in the literature to better understand plantar tissue stress exposure (Patry et al., 2013). These authors reviewed the role of pressure and shear forces in the pathogenesis of diabetic foot ulcer, stating that in-shoe peak plantar pressure is the only reliable variable that can be used to prevent diabetic foot ulcer; an in-shoe peak plantar pressure threshold value of 200 kPa has been suggested. Other variables, such as peak pressure gradient and peak maximal subsurface shear stress and depth, seem to be of additional utility.

Regarding other disorders or diseases, it has been suggested that gait speed or gait variability may be a marker of risk to develop Alzheimer's disease (Gillain et al., 2016). Also, gait speed may be useful as a reliable, easily attainable, and a non-invasive risk factor for cognitive decline (Mielke et al., 2013). That understanding the relationship between early gait disturbances and early cognitive changes may help identify older adults at risk of experiencing mobility decline, falls, and progression to dementia (Montero-Odasso et al., 2014). Or even that cognitive impairments in Parkinson's disease manifest as deficits in the speed of processing, working memory, and executive function and attention abilities (Stegemoller et al., 2014). The gait impairment in Parkinson's disease is well documented to include reduced speed, shortened step lengths, and increased step-to-step variability. Furthermore, early identification of people at risk of functional decline is essential for delivering targeted preventive interventions (Jonkman et al., 2018), and better understand those who benefit most from interventions (Kikkert et al., 2016). Gait pattern in patients with arthritis was characterized by decreased walking speed, reduced cadence, reduced stride length, reduced ankle power, increased double limb support time, and increased peak plantar pressures at the forefoot (Carroll et al., 2015). Extensive examples are demonstrating different conditions where gait patterns may clear the role of interventions.

3.6. Gait parameters that can be used as expression of functional capacity in older adults

Several gait parameters have been used to assess functional capacity of older adults. Table 3 shows the parameters with significant effects in patients with different clinical conditions.

Table 3 - Gait parameters used to assess functional capacity of older adults.

Gait parameters	Change/adaptation	Patient clinical condition	Controls	Author(s)
Spatial-temporal parameters	decreased stride length	multiple sclerosis patients	healthy controls	Wonneberger and Schmidt (2015)
		patients with inflammatory arthritis	healthy controls	
	decreased step cadence	multiple sclerosis patients	healthy controls	Carroll, Parmar, Dalbeth, Boocock, and Rome (2015)
		patients with inflammatory arthritis	healthy controls	

	increased double limb support time	patients with inflammatory arthritis	healthy controls	Wonneberger and Schmidt (2015)
Range of motion	decreased static range of motion at the ankle and first metatarsophalangeal joints	diabetic patients with a history of peripheral neuropathic ulceration	Non-diabetes reference group	
Gait speed	walking speed was on average 0.17 ms slower	diabetic patients with a history of peripheral neuropathic ulceration	Non-diabetes reference group	Carroll et al. (2015)
	decreased walking speed	patients with inflammatory arthritis	healthy controls	
	decreased walking speed	OA (and children)	adolescence and adulthood	Carroll et al. (2015)
	gait speed and mortality reduction	OA	3 groups of OA: participants were classified as improved at 1 year, transiently improved, or never improved	Hardy, Perera, Roumani, Chandler, and Studenski (2007)
	gait speed and increased risk of cardiovascular mortality	OA	OA control group	
	gait speed and physical and cognitive function	OA	No control group	Dumurgier et al. (2009)
	gait speed and cognitive function	mild cognitive impairment OA	OA control group	Elbaz et al. (2013)
	gait speed and cognitive function	OA	No control group	
Gait loading - (ground reaction forces and plantar pressures)	Lower (6%) vertical ground reaction force 2nd peak	diabetic patients with a history of peripheral neuropathic ulceration	Non-diabetes reference group	Garcia-Pinillos, Cozar-Barba, Munoz-Jimenez, Soto-Hermoso, and Latorre-Roman (2016)
	Elevated peak plantar pressures	OA with diabetes having neuropathy	OA with diabetes not having neuropathy	
	Decreased peak plantar pressures at the forefoot	OA patients with inflammatory arthritis	OA healthy controls	Doi et al. (2014)
	Decreased ankle power	OA patients with inflammatory arthritis	OA healthy controls	
Gait variability (frequency,	Gait pattern	OA with falls history	Healthy OA and adults	Mielke et al. (2013)

regularity, symmetry)				

OA = older adults

A recent study established lifespan normative reference values of widely used spatiotemporal and plantar pressure parameters (McKay et al., 2017). The authors concluded that older adults walked at a comparatively slower speed than in adulthood. Several studies reported more significant gait variability (e.g., the variability of step length and speed), a lower step length, and reduced rolling foot movements with additional shifts of plantar pressure in older adults (Springer et al., 2006). According to Cruz-Jimenez (2017), reduced walking speed is the most consistent age-related change; nevertheless, there are other contributors to an altered gait: impaired balance and stability, lower extremity strength, and the fear of falling. Indeed, gait speed is a valid, reliable, and sensitive measure appropriate for assessing and monitoring functional status and overall health in a wide range of populations (Middleton et al., 2015). However, few studies have used gait speed as a tool (Garcia-Pinillos et al., 2016).

Thingstad et al. (2015) analyzed gait restoration as an important goal of rehabilitation after a hip fracture. Numerous spatial and temporal gait variables have been reported in the literature. Still, there is little agreement on which gait variables should be reported beyond gait speed and redundant in describing gait recovery following hip fracture. Four distinct gait domains are proposed: double support time, walk ratio, variability of step velocity, and single support asymmetry. Cognitive decline, low grip strength, extracapsular fracture, and male gender, but not pain or age, were identified as significant predictors of impaired gait. These core variables were associated with known predictors of poor outcome after hip fracture. They should warrant further assessment to confirm their importance as outcome variables in addition to gait speed.

A meta-analysis of individual data from 9 selected cohorts was conducted and concluded that gait speed was associated with older adults' survival (Studenski et al., 2011). Accordingly, slow walking speed in older people is strongly associated with an increased risk of cardiovascular mortality (Dumurgier et al., 2009; Elbaz et al., 2013). A cross-sectional population based on a sample of 1.112 older adults showed that the average walking speed of the elderly was 0.81 m/s-0.78 m/s among women and 0.86 m/s among men (Garcia-Pinillos et al., 2016). Still, the usual walking pace is an independent predictor of all-cause mortality in men but not in women among older adults approaching age 65 years or more (Liu et al., 2016). Since gait speed is easily measured, clinically interpretable, and potentially modifiable, it may be a useful "vital sign" for older adults (Hardy et al., 2007). Yet, further research is needed to determine whether interventions to improve gait speed affect survival.

Plantar center of pressure variables during gait have been used to predict injury risk. For instance, determining the effect of age on the center of pressure trajectory during barefoot gait at a self-selected speed (Sole et al., 2017). The results did not necessarily imply that aging itself causes the observed correlation. Further evidence is needed to determine whether the laterally placed center of pressure during roll-off may be a useful factor for determining the risk for falling in the older population or as a risk for future injuries or overuse disorders.

Regarding gait loading, it has been stated that peak pressures increase during childhood to older adults (McKay et al., 2017). Also, children demonstrated the highest peak pressures beneath the rearfoot, while adolescents, adults, and older adults showed the most elevated pressures at the forefoot. The main factors influencing spatiotemporal and pressure parameters were increased age, height, body mass, waist circumference, ankle dorsiflexion, and plantarflexion strength. However, besides increased body weight (Butterworth et al., 2014), other factors have been associated with high plantar pressure levels, such as foot structure(O'Brien & Tyndyk, 2014) and walking strategy (Sullivan et al., 2015). On the other hand, it has been shown that plantar pressure presented a consistent pattern in the elderly (Franco et al., 2015). The asymmetry indexes observed suggests that older adults are exposed to repetitive asymmetric loading during locomotion. Nevertheless, the repeatability and variability of the plantar pressure during walking are essential components in the clinical assessment of the elderly (Franco et al., 2015).

Thus, the information derived from plantar pressure and ground reaction forces measures is essential in gait and posture research for diagnosing lower limb problems and injury prevention (Amemiya et al., 2014; Lee et al., 2007; Razak et al., 2012; Robinson et al., 2013; Simmonds et al., 2012), among other applications, such as analyzing the effects of a treatment or intervention (W. M. Chen et al., 2015; Iunes et al., 2014; Parkatti et al., 2012).

3.7. Effects of physical activity and exercise interventions on gait parameters in the older population

The interest on exercise and physical activity effects on dual-task performance has grown rapidly in the last decade, due to the aging global population (Gobbo et al., 2014). While the concept of “healthy aging” has traditionally focused on prevention disease, greater efforts are needed to reduce frailty and dependency and maintain independent physical and cognitive function among older adults (Bauman et al., 2016). There is consistent evidence about the changes in several gait parameters with aging, such as the spatial-temporal, speed and plantar pressure parameters. Still, the available literature is unclear about the effects induced by exercise on the maintenance of gait attributes in older people.

The impact of exercise programs on functional fitness parameters is evident, despite the heterogeneity of the interventions and the fact that most of the studies are focused on clinical populations (M. S. Chen et al., 2015; Conn, 2010; Liu et al., 2011; Parmenter et al., 2011; Rubenstein et al., 2000; Thune-Boyle et al., 2012; Tseng et al., 2011). Doi et al. (2014) refer that multicomponent exercise training has been shown to increase physical function in the elderly, by means of improving gait, and thus, improving the physical health of the elderly. And some studies highlight that exercise training may improve balance, gait and reduce the risk of falling (M. S. Chen et al., 2015; Hortobagyi et al., 2015; Morrison et al., 2014; Wong-Yu & Mak, 2015). Okubo et al. (2016) examined the effects of stepping interventions on fall (risk and incidence), in older people. This meta-analyses of seven RCTs (n=660) showed that the stepping interventions significantly reduced the rate of falls and the proportion of fallers. Their findings indicate that both reactive and volitional stepping interventions reduce falls among older adults by approximately 50%. These results suggest that this clinically significant reduction may be due to improvements in reaction time, gait, balance and balance recovery, but not in strength.

Though, it is questionable which physical activity level or which exercise intervention would affect or minimize the age-related gait parameters. A systematic review, aiming to determine the efficacy of exercise-based interventions (randomized controlled trials - RCT) on improving performance-based measures of physical function and markers of physical frailty in community-dwelling, frail older people, has been conducted (Gine-Garriga et al., 2014). For inclusion, the RCT had to compare an exercise intervention with a control or another exercise intervention and assess performance-based measures of physical function such as mobility and gait, or disability in ADLs. The main results demonstrated the benefits of exercise to improve normal gait speed, fast gait speed. Results were inconclusive for endurance outcomes, balance and ADL functional mobility. Moreover, the evidence comparing different modalities of exercise is scarce and heterogeneous. The authors concluded that exercise programs have some benefits in frail older people, although uncertainty still exists regarding which exercise characteristics (i.e., type, frequency, duration, intensity, progression and volume) are most effective.

Gobbo et al. (2014) reviewed the existing evidence of 6 randomized controlled trials (RCT), one controlled trial (CT), and one uncontrolled trial (UT) on the potential relationship between exercise and improvement of static and dynamic balance during dual-task in healthy older adults, and secondary outcomes in other physical and cognitive indices. Similarly, the authors identified numerous limitations mainly focused on the lack of a common and standardized method to evaluate the balance during the dual-task performance. Additionally, exercise protocols were extensively distinct, and generally lacked reporting measures. These findings do not support that exercises used in these interventions entail clear and noteworthy benefits on static or dynamic balance improvements during dual-task performance, and that innovative measures and exercise programs may need to be developed before efficacious screening and treatment strategies can be used in clinical settings.

Regarding the level of physical activity, it was concluded that physical activity reduces the age-related decline in functional capacity and maintains muscle strength and mass among adults aged 65–85 years (Paterson & Warburton, 2010). Paterson and Warburton (2010) and Tak et al. (2013), reported a 50% reduction in the relative risk of developing functional limitations or disability among older adults participating in moderate-intensity physical activity. Likewise, the functional status may be preserved with even lower amounts of physical activity among older groups, aged 70–75 years (Paterson & Warburton, 2010). Hackney et al. (2015), showed that 20 sessions of 90-minutes of adapted tango classes over 12 weeks improved mobility, backward and fast gait speeds, and motor-cognitive function, compared to a control group that received an education program. These gains were maintained 3 months after the intervention. Hortobagyi et al. (2015) determined the effects of strength, power, coordination, and multimodal exercise training on healthy older adults' habitual and fast gait speed. The authors concluded that commonly used exercise interventions can functionally and clinically increase habitual and fast gait speed and thus, helping to slow the loss of gait speed or delay its onset.

Chen et al. (2015) developed an effective exercise training program for enhancing the postural stability and gait function of chronically ill patients to avoid falls. This study revealed that younger patients attained more positive results than older patients, and women attained more positive results than men. Nonetheless, the authors concluded that regular exercise is a means of preventing falls. Besides, the authors suggested that government and hospitals should increase promotional measures in aging communities to encourage regular exercise among older adults. Doi et al. (2014) investigated the effect of a multicomponent exercise programme, performed for 90-min, twice a week over six months, on gait in an intervention group of older adults when compared with a control group. The program had a significant effect on gait speed and stride length. In the same approach, significant positive meta-effect of different types of exercise interventions from randomized controlled trials have been shown to improve preferred gait speed (Lopopolo et al., 2006; Van Abbema et al., 2015) and dual-task walking in older adults (Plummer et al., 2015). Azadian et al. (2016) compared the effect of two different approaches of dual-task training and executive training on pattern of gait in older adults with balance impairment. Participants in experimental groups received 45-min training sessions, 3 times a week for 8 weeks. Authors reported significant changes that after training, on walking speed, length of stride and step, times of stride, step, single support, and double support.

Daily activities require the ability to dual task (DT), using cognitive resources while walking to negotiate complex environmental conditions. For older adults, these additional cognitive demands often lead to reduced gait quality that increases the risk of falls (Dorfman et al., 2014). van Het Reve et al. (2014) stated that the combination of physical and cognitive training exercise interventions is assumed to be more beneficial in improving walking and cognitive functioning compared to isolated cognitive or physical training. These authors conducted a multicenter parallel RCT comparing a motor (strength-balance) to a cognitive-motor (strength-balance-cognitive) exercise program, for 12 weeks. They were able to show that combining strength-balance training with specific cognitive training had a positive additional effect on dual task costs of walking, gait initiation, and divided attention. The authors concluded that within-group comparison revealed significant improvements in dual task costs of walking (preferred speed and fast speed): velocity, step time, step length, simple reaction time, executive functioning, divided attention, fear of falling, and fall rate.

Dorfman et al. (2014) conducted a combined intervention, consisting of treadmill training while performing dual task exercises based on a repeated measures design. After 6 weeks of treadmill training plus a dual task program, older adults with a history of multiple falls demonstrated improved scores on tests of mobility (balance, dynamic gait index, and gait speed during usual walking and while dual task), functional performance tasks, and cognitive performance. Furthermore, also the quality of life (SF-36) and the physical activity (Physical Activity Scale for Elderly) improved. The authors concluded that dual task training can be readily implemented by therapists as a component of a fall-risk reduction training program.

Finally, Kim and Hwangbo (2015) examined the effect of 8 weeks gait training using obstacle on the plantar pressure and contact time in elderly women. Foot contact time did not decrease right before crossing the obstacle but decreased right after crossing the obstacle. Foot pressure moved from the end of the frontal foot to the midfoot and heel right before crossing the obstacle. Foot pressure increased in lesser toe right after crossing the obstacle. The main findings were significant decreases/increases in plantar pressure values under the longitudinal arch and medial forefoot region after the intervention. However, there were no statistically significant differences in measured values between the groups. The authors concluded that the load of the foot shifted after the intervention in a forward medial direction, which puts more loads on the longitudinal arch, medial metatarsal head areas and the big toe. The effect of the intervention was not proved, and biomechanical shoes may be recommended for this population.

3.8. Discussion

Exercise and physical activity have a crucial role on the preservation of physical capacities and in maintaining autonomy in further years. As for younger and middle-aged adults, regular physical activity (PA) and moderate-to-vigorous PA (MVPA) are important for improving cardiovascular fitness and are good predictors of physiological risk factors, morbidity and mortality in older adults. Gait parameters are objective means of assessing the functional status of older adults. The present review has examined the available research on gait alterations in older adults, and how those alterations are affected by aging process, physical and cognitive status and adverse outcomes. Furthermore, we also analyzed the evidences supporting the role of physical exercise on the promotion of independency in later age stages.

Gait analysis is a well-established tool for the quantitative assessment of gait disturbances providing functional diagnosis, assessment for treatment planning, and monitoring of disease progress (Baker et al., 2016). Technology and software development are promising fields, that will certainly contribute for further developments. According to Bridenbaugh and Kressig (2014) quantitative gait analysis, particularly performed during dual task conditions, can detect gait deficits that cannot yet be seen by the naked eye, even by a trained specialist. In this line, Baker et al. (2016) provided an overview on guidelines for managing a clinical gait analysis service, since an appropriate gait analysis prescription and the reliability of data obtained are required in the clinical environment. Building databases of plantar pressure values could be a robust reference data to identify suspicious foot loading patterns in older adults with different conditions. Pothier et al. (2018) pointed out different tools to prevent functional decline in older people. They stated that the assessments of mobility, functional status, fall risk and cognition should be an integral part of every comprehensive geriatric assessment. Quantitative gait analysis allows not only the early detection of gait deficits and fall risk, but also of cognitive deficits. Early detection allows for timely implementation of targeted interventions to improve gait and/or cognition. Results of this narrative review suggest that aerobic/resistance exercise and computerized dual-task training are two non-pharmacological interventions by which spontaneous walking speed, a functional vital sign, can be clinically improved in older adults. Finally, another interesting approach was provided by Lacroix et al. (2017) in the first systematic literature analysis that has been conducted to quantify the effectiveness of supervised vs. unsupervised balance and/or resistance training programs on measures of balance and muscle strength/power in healthy older adults. The authors suggested that supervised balance and/or resistance training programs were more effective than unsupervised programs in older adults. Therefore, it is recommended to include supervised sessions (i.e., 2 out of 3 sessions/week) in balance/resistance training programs to effectively improve balance and muscle strength/power in older adults.

However, readers should be remembered that the results from findings in clinical trials regarding the effects of exercise on the other gait parameters are inconsistent and scarce, namely for the kinetic variables representative of biomechanical loading.

3.9. Future perspectives

Regular exercise is a process for preventing falls and enhance autonomy in older adults. Currently, it appears that exercise and physical activity are beneficial to the maintenance of gait parameters, which in turn may have a positive impact on physical performance and autonomy. Thus, Health and Fitness centers should increase promotional strategies in aging communities to encourage regular exercise among the elderly. However, much controversy remains regarding the effects of exercise and physical activity on the gait pattern of older adults.

Aging is associated with alterations in foot characteristics contributing to altered plantar loading patterns during gait (Scott et al., 2007). Further research is needed to increase evidence regarding the most accurate gait parameters for the identification of risk of falling and gait disorders or impairment. It is important that studies are performed using standardized protocols that would allow later comparisons of the results obtained by different authors. The undertaking of such studies, especially RCTs, might afford more reliable answers. Additionally, it will be important to consider a standardized analytical approach to gait analysis that will provide clinicians and researchers with objective evidence of foot function and adaptations in older people with or without a specific clinical condition (Carroll et al., 2015).

Finally, a clinical classification of dismobility could provide the inpatient health care team with meaningful information about the older patients' underlying health conditions and future prognosis and provide an opportunity to discuss and implement treatment options with patients and their families.

3.10. References

Aboutorabi, A., Arazpour, M., Bahramizadeh, M., Hutchins, S. W., & Fadayevatan, R. (2016). The effect of aging on gait parameters in able-bodied older subjects: a literature review. Aging Clinical and Experimental Research, 28(3), 393-405. doi:10.1007/s40520-015-0420-6

Amboni, M., Barone, P., & Hausdorff, J. M. (2013). Cognitive Contributions to Gait and Falls: Evidence and Implications. Movement Disorders, 28(11), 1520-1533. doi:10.1002/mds.25674

Ambrose, A. F., Cruz, L., & Paul, G. (2015). Falls and Fractures: A systematic approach to screening and prevention. Maturitas, 82(1), 85-93. doi:10.1016/j.maturitas.2015.06.035

Amemiya, A., Noguchi, H., Oe, M., Ohashi, Y., Ueki, K., Kadowaki, T., . . . Sanada, H. (2014). Elevated plantar pressure in diabetic patients and its relationship with their gait features. Gait & Posture, 40(3), 408-414. doi:10.1016/j.gaitpost.2014.05.063

Ayoubi, F., Launay, C. P., Annweiler, C., & Beauchet, O. (2015). Fear of falling and gait variability in older adults: a systematic review and meta-analysis. J Am Med Dir Assoc, 16(1), 14-19. doi:10.1016/j.jamda.2014.06.020

Azadian, E., Torbati, H. R., Kakhki, A. R., & Farahpour, N. (2016). The effect of dual task and executive training on pattern of gait in older adults with balance impairment: A Randomized controlled trial. Arch Gerontol Geriatr, 62, 83-89. doi:10.1016/j.archger.2015.10.001

Baker, R., Esquenazi, A., Benedetti, M. G., & Desloovere, K. (2016). Gait analysis: clinical facts. Eur J Phys Rehabil Med, 52(4), 560-574.

Bauman, A., Merom, D., Bull, F. C., Buchner, D. M., & Fiatarone Singh, M. A. (2016). Updating the Evidence for Physical Activity: Summative Reviews of the Epidemiological Evidence, Prevalence, and Interventions to Promote "Active Aging". Gerontologist, 56 Suppl 2, S268-280. doi:10.1093/geront/gnw031

Bridenbaugh, S. A., & Kressig, R. W. (2011). Laboratory review: the role of gait analysis in seniors' mobility and fall prevention. Gerontology, 57(3), 256-264. doi:10.1159/000322194

Bridenbaugh, S. A., & Kressig, R. W. (2014). Quantitative gait disturbances in older adults with cognitive impairments. Curr Pharm Des, 20(19), 3165-3172. doi:10.2174/13816128113196660688

Brown, S. J., Handsaker, J. C., Maganaris, C. N., Bowling, F. L., Boulton, A. J., & Reeves, N. D. (2016). Altered joint moment strategy during stair walking in diabetes patients with and without peripheral neuropathy. Gait & Posture, 46, 188-193. doi:10.1016/j.gaitpost.2016.03.007

Bruce-Keller, A. J., Brouillette, R. M., Tudor-Locke, C., Foil, H. C., Gahan, W. P., Nye, D. M., . . . Keller, J. N. (2012). Relationship between cognitive domains, physical performance, and gait in elderly and demented subjects. J Alzheimers Dis, 30(4), 899-908. doi:10.3233/JAD-2012-120025

Busch, T. D., Duarte, Y. A., Nunes, D. P., Lebrao, M. L., Naslavsky, M. S., Rodrigues, A. D., & Amaro, E. (2015). Factors associated with lower gait speed among the elderly living in a developing country: a cross-sectional population-based study. Bmc Geriatrics, 15. doi:ARTN 3510.1186/s12877-015-0031-2

Butterworth, P. A., Landorf, K. B., Gilleard, W., Urquhart, D. M., & Menz, H. B. (2014). The association between body composition and foot structure and function: a systematic review. Obesity Reviews, 15(4), 348-357. doi:10.1111/obr.12130

Carroll, M., Parmar, P., Dalbeth, N., Boocock, M., & Rome, K. (2015). Gait characteristics associated with the foot and ankle in inflammatory arthritis: a systematic review and meta-analysis. Bmc Musculoskeletal Disorders, 16. doi:ARTN 13410.1186/s12891-015-0596-0

Chen, M. S., Lin, T. C., & Jiang, B. C. (2015). Aerobic and resistance exercise training program intervention for enhancing gait function in elderly and chronically ill Taiwanese patients. Public Health, 129(8), 1114-1124. doi:10.1016/j.puhe.2015.04.018

Chen, W. M., Lee, S. J., & Lee, P. V. S. (2015). Plantar pressure relief under the metatarsal heads - Therapeutic insole design using three-dimensional finite element model of the foot. Journal of Biomechanics, 48(4), 659-665. doi:10.1016/j.jbiomech.2014.12.043

Chodzko-Zajko, W. J., Proctor, D. N., Singh, M. A. F., Minson, C. T., Nigg, C. R., Salem, G. J., & Skinner, J. S. (2009). Exercise and Physical Activity for Older Adults. Medicine and Science in Sports and Exercise, 41(7), 1510-1530. doi:10.1249/MSS.0b013e3181a0c95c

Conn, V. S. (2010). Anxiety Outcomes After Physical Activity Interventions Meta-Analysis Findings. Nursing Research, 59(3), 224-231. doi:10.1097/NNR.0b013e3181dbb2f8

Cruz-Jimenez, M. (2017). Normal Changes in Gait and Mobility Problems in the Elderly. Physical Medicine and Rehabilitation Clinics of North America, 28(4), 713-+. doi:10.1016/j.pmr.2017.06.005

Doi, T., Shimada, H., Makizako, H., Tsutsumimoto, K., Uemura, K., Anan, Y., & Suzuki, T. (2014). Cognitive function and gait speed under normal and dual-task walking among older adults with mild cognitive impairment. Bmc Neurology, 14. doi:Artn 6710.1186/1471-2377-14-67

Dorfman, M., Herman, T., Brozgol, M., Shema, S., Weiss, A., Hausdorff, J. M., & Mirelman, A. (2014). Dual-Task Training on a Treadmill to Improve Gait and Cognitive Function in Elderly Idiopathic Fallers. Journal of Neurologic Physical Therapy, 38(4), 246-253. doi:10.1097/Npt.0000000000000057

Dumurgier, J., Elbaz, A., Ducimetiere, P., Tavernier, B., Alperovitch, A., & Tzourio, C. (2009). Slow walking speed and cardiovascular death in well functioning older adults: prospective cohort study. Bmj-British Medical Journal, 339. doi:ARTN b446010.1136/bmj.b4460

Elbaz, A., Sabia, S., Brunner, E., Shipley, M., Marmot, M., Kivimaki, M., & Singh-Manoux, A. (2013). Association of walking speed in late midlife with mortality: results from the Whitehall II cohort study. Age, 35(3), 943-952. doi:10.1007/s11357-012-9387-9

Fernando, M., Crowther, R., Lazzarini, P., Sangla, K., Cunningham, M., Buttner, P., & Golledge, J. (2013). Biomechanical characteristics of peripheral diabetic neuropathy: A systematic review and meta-analysis of findings from the gait cycle, muscle activity and dynamic barefoot plantar pressure. Clinical Biomechanics, 28(8), 831-845. doi:10.1016/j.clinbiomech.2013.08.004

Franco, P. S., Silva, C. B., Rocha, E. S., & Carpes, F. P. (2015). Variability and repeatability analysis of plantar pressure during gait in older people. Rev Bras Reumatol, 55(5), 427-433. doi:10.1016/j.rbr.2015.03.006

Ganz, D. A., Bao, Y., Shekelle, P. G., & Rubenstein, L. Z. (2007). Will my patient fall? Jama-Journal of the American Medical Association, 297(1), 77-86. doi:DOI 10.1001/jama.297.1.77

Garcia-Pinillos, F., Cozar-Barba, M., Munoz-Jimenez, M., Soto-Hermoso, V., & Latorre-Roman, P. (2016). Gait speed in older people: an easy test for detecting cognitive impairment, functional independence, and health state. Psychogeriatrics, 16(3), 165-171. doi:10.1111/psyg.12133

Gillain, S., Drame, M., Lekeu, F., Wojtasik, V., Ricour, C., Croisier, J. L., . . . Petermans, J. (2016). Gait speed or gait variability, which one to use as a marker of risk to develop Alzheimer disease? A pilot study. Aging Clinical and Experimental Research, 28(2), 249-255. doi:10.1007/s40520-015-0392-6

Gine-Garriga, M., Roque-Figuls, M., Coll-Planas, L., Sitja-Rabert, M., & Salva, A. (2014). Physical Exercise Interventions for Improving Performance-Based Measures of Physical Function in Community-Dwelling, Frail Older Adults: A Systematic Review and Meta-Analysis. Archives of Physical Medicine and Rehabilitation, 95(4), 753-769. doi:10.1016/j.apmr.2013.11.007

Gobbo, S., Bergamin, M., Sieverdes, J. C., Ermolao, A., & Zaccaria, M. (2014). Effects of exercise on dual-task ability and balance in older adults: A systematic review. Archives of Gerontology and Geriatrics, 58(2), 177-187. doi:10.1016/j.archger.2013.10.001

Hackney, M. E., Hall, C. D., Echt, K. V., & Wolf, S. L. (2015). Multimodal Exercise Benefits Mobility in Older Adults With Visual Impairment: A Preliminary Study. Journal of Aging and Physical Activity, 23(4), 630-639. doi:10.1123/japa.2014-0008

Hardy, S. E., Perera, S., Roumani, Y. F., Chandler, J. M., & Studenski, S. A. (2007). Improvement in usual gait speed predicts better survival in older adults. Journal of the American Geriatrics Society, 55(11), 1727-1734. doi:10.1111/j.1532-5415.2007.01413.x

Hazari, A., Maiya, A. G., Shivashankara, K. N., Agouris, I., Monteiro, A., Jadhav, R., . . . Mayya, S. S. (2016). Kinetics and kinematics of diabetic foot in type 2 diabetes mellitus with and without peripheral neuropathy: a systematic review and meta-analysis. Springerplus, 5. doi:ARTN 181910.1186/s40064-016-3405-9

Higuchi, Y., Sudo, H., Tanaka, N., Fuchioka, S., & Hayashi, Y. (2004). Does fear of falling relate to low physical function in frail elderly persons?: associations of fear of falling, balance, and gait. J Jpn Phys Ther Assoc, 7(1), 41-47. doi:10.1298/jjpta.7.41

Hortobagyi, T., Lesinski, M., Gabler, M., VanSwearingen, J. M., Malatesta, D., & Granacher, U. (2015). Effects of Three Types of Exercise Interventions on Healthy Old Adults' Gait Speed: A Systematic Review and Meta-Analysis. Sports Med, 45(12), 1627-1643. doi:10.1007/s40279-015-0371-2

Iunes, D. H., Rocha, C. B., Borges, N. C., Marcon, C. O., Pereira, V. M., & Carvalho, L. C. (2014). Self-care associated with home exercises in patients with type 2 diabetes mellitus. Plos One, 9(12), e114151. doi:10.1371/journal.pone.0114151

Jonkman, N. H., Del Panta, V., Hoekstra, T., Colpo, M., van Schoor, N. M., Bandinelli, S., . . . Maier, A. B. (2018). Predicting Trajectories of Functional Decline in 60- to 70-Year-Old People. Gerontology, 64(3), 212-221. doi:10.1159/000485135

Kikkert, L. H. J., Vuillerme, N., van Campen, J. P., Hortobagyi, T., & Lamoth, C. J. (2016). Walking ability to predict future cognitive decline in old adults: A scoping review. Aging Res Rev, 27, 1-14. doi:10.1016/j.arr.2016.02.001

Kim, S. G., & Hwangbo, G. (2015). The effect of obstacle gait training on the plantar pressure and contact time of elderly women. Arch Gerontol Geriatr, 60(3), 401-404. doi:10.1016/j.archger.2015.02.007

Krishnan, C., Washabaugh, E. P., Reid, C. E., Althoen, M. M., & Ranganathan, R. (2018). Learning new gait patterns: Age-related differences in skill acquisition and interlimb transfer. Exp Gerontol, 111, 45-52. doi:10.1016/j.exger.2018.07.001

Lacroix, A., Hortobagyi, T., Beurskens, R., & Granacher, U. (2017). Effects of Supervised vs. Unsupervised Training Programs on Balance and Muscle Strength in Older Adults: A Systematic Review and Meta-Analysis. Sports Med, 47(11), 2341-2361. doi:10.1007/s40279-017-0747-6

LaRoche, D. P., Marques, N. R., Masley, E. A., Morcelli-Gotardo, M. H., & Cook, S. B. (2014). Increasing Strength-to-Weight Ratio Changes Gait Timing but not Walking Speed in Older Adults. Medicine and Science in Sports and Exercise, 46(5), 830-830. doi:DOI 10.1249/01.mss.0000495986.11866.38

Lee, M. Y., Lin, C. F., & Soon, K. S. (2007). New foot pressure activated sensory compensation system for posture-control enhancement in Amputees. Ieee-Asme Transactions on Mechatronics, 12(3), 236-243. doi:10.1109/Tmech.2007.897234

Liu, B., Hu, X. H., Zhang, Q., Fan, Y. C., Li, J., Zou, R., . . . Wang, J. P. (2016). Usual walking speed and all-cause mortality risk in older people: A systematic review and meta-analysis. Gait & Posture, 44, 172-177. doi:10.1016/j.gaitpost.2015.12.008

Liu, Y. P., Hu, F. L., Li, D. D., Wang, F., Zhu, L., Chen, W. Y., . . . Zhao, Y. S. (2011). Does Physical Activity Reduce the Risk of Prostate Cancer? A Systematic Review and Meta-analysis. European Urology, 60(5), 1029-1044. doi:10.1016/j.eururo.2011.07.007

Lopopolo, R. B., Greco, M., Sullivan, D., Craik, R. L., & Mangione, K. K. (2006). Effect of therapeutic exercise on gait speed in community-dwelling elderly people: A meta-analysis. Physical Therapy, 86(4), 520-540. doi:DOI 10.1093/ptj/86.4.520

Mahlknecht, P., Kiechl, S., Bloem, B. R., Willeit, J., Scherfler, C., Gasperi, A., . . . Seppi, K. (2013). Prevalence and Burden of Gait Disorders in Elderly Men and Women Aged 60-97 Years: A Population-Based Study. Plos One, 8(7). doi:ARTN e6962710.1371/journal.pone.0069627

McKay, M. J., Baldwin, J. N., Ferreira, P., Simic, M., Vanicek, N., Wojciechowski, E., . . . Consortium, N. P. (2017). Spatiotemporal and plantar pressure patterns of 1000 healthy individuals aged 3-101 years. Gait & Posture, 58, 78-87. doi:10.1016/j.gaitpost.2017.07.004

Mickle, K. J., Munro, B. J., Lord, S. R., Menz, H. B., & Steele, J. R. (2010). Foot Pain, Plantar Pressures, and Falls in Older People: A Prospective Study. Journal of the American Geriatrics Society, 58(10), 1936-1940. doi:10.1111/j.1532-5415.2010.03061.x

Middleton, A., Fritz, S. L., & Lusardi, M. (2015). Walking Speed: The Functional Vital Sign. Journal of Aging and Physical Activity, 23(2), 314-322. doi:10.1123/japa.2013-0236

Mielke, M. M., Roberts, R. O., Savica, R., Cha, R., Drubach, D. I., Christianson, T., . . . Petersen, R. C. (2013). Assessing the Temporal Relationship Between Cognition and Gait: Slow Gait Predicts Cognitive Decline in the Mayo Clinic Study of Aging. Journals of Gerontology Series a-Biological Sciences and Medical Sciences, 68(8), 929-937. doi:10.1093/gerona/gls256

Moniz-Pereira, V., Carnide, F., Machado, M., Andre, H., & Veloso, A. P. (2012). Falls in Portuguese older people: procedures and preliminary results of the study Biomechanics of Locomotion in the Elderly. Acta Reumatologica Portuguesa, 37(4), 324-332.

Moniz-Pereira, V., Carnide, F., Ramalho, F., Andre, H., Machado, M., Santos-Rocha, R., & Veloso, A. P. (2013). Using a multifactorial approach to determine fall risk profiles in portuguese older adults. Acta Reumatologica Portuguesa, 38(4), 263-272.

Montero-Odasso, M., Oteng-Amoako, A., Speechley, M., Gopaul, K., Beauchet, O., Annweiler, C., & Muir-Hunter, S. W. (2014). The Motor Signature of Mild Cognitive Impairment: Results From the Gait and Brain Study. Journals of Gerontology Series a-Biological Sciences and Medical Sciences, 69(11), 1415-1421. doi:10.1093/gerona/glu155

Montero-Odasso, M., Verghese, J., Beauchet, O., & Hausdorff, J. M. (2012). Gait and Cognition: A Complementary Approach to Understanding Brain Function and the Risk of Falling. Journal of the American Geriatrics Society, 60(11), 2127-2136. doi:10.1111/j.1532-5415.2012.04209.x

Morrison, S., Colberg, S. R., Parson, H. K., & Vinik, A. I. (2014). Exercise improves gait, reaction time and postural stability in older adults with type 2 diabetes and neuropathy. Journal of Diabetes and Its Complications, 28(5), 715-722. doi:10.1016/j.jdiacomp.2014.04.007

Mortaza, N., Abu Osman, N. A., & Mehdikhani, N. (2014). Are the spatio-temporal parameters of gait capable of distinguishing a faller from a non-faller elderly? Eur J Phys Rehabil Med, 50(6), 677-691.

Nakajima, K., Anzai, E., Iwakami, Y., Ino, S., Yamashita, K., & Ohta, Y. (2014). Measuring gait pattern in elderly individuals by using a plantar pressure measurement device. Technol Health Care, 22(6), 805-815. doi:10.3233/THC-140856

O'Brien, D. L., & Tyndyk, M. (2014). Effect of arch type and Body Mass Index on plantar pressure distribution during stance phase of gait. Acta Bioeng Biomech, 16(2), 131-135.

Okubo, Y., Osuka, Y., Jung, S., Rafael, F., Tsujimoto, T., Aiba, T., . . . Tanaka, K. (2016). Walking can be more effective than balance training in fall prevention among community-dwelling older adults. Geriatr Gerontol Int, 16(1), 118-125. doi:10.1111/ggi.12444

Parkatti, T., Perttunen, J., & Wacker, P. (2012). Improvements in functional capacity from Nordic walking: a randomized-controlled trial among elderly people. J Aging Phys Act, 20(1), 93-105. doi:10.1123/japa.20.1.93

Parmenter, B. J., Raymond, J., Dinnen, P., & Singh, M. A. (2011). A systematic review of randomized controlled trials: Walking versus alternative exercise prescription as treatment for intermittent claudication. Atherosclerosis, 218(1), 1-12. doi:10.1016/j.atherosclerosis.2011.04.024

Paterson, D. H., & Warburton, D. E. (2010). Physical activity and functional limitations in older adults: a systematic review related to Canada's Physical Activity Guidelines. Int J Behav Nutr Phys Act, 7, 38. doi:10.1186/1479-5868-7-38

Patry, J., Belley, R., Cote, M., & Chateau-Degat, M. L. (2013). Plantar pressures, plantar forces, and their influence on the pathogenesis of diabetic foot ulcers: a review. J Am Podiatr Med Assoc, 103(4), 322-332. doi:10.7547/1030322

Peel, N. M., & Kuys, S. S. (2013). Walking Activity of Older Patients in Rehabilitation: A Prospective Study. J Frailty Aging, 2(1), 22-26. doi:10.14283/jfa.2013.4

Plummer, P., Zukowski, L. A., Giuliani, C., Hall, A. M., & Zurakowski, D. (2015). Effects of Physical Exercise Interventions on Gait-Related Dual-Task Interference in Older Adults: A Systematic Review and Meta-Analysis. Gerontology, 62(1), 94-117. doi:10.1159/000371577

Pothier, K., Gagnon, C., Fraser, S. A., Lussier, M., Desjardins-Crepeau, L., Berryman, N., . . . Bherer, L. (2018). A comparison of the impact of physical exercise, cognitive training and combined intervention on spontaneous walking speed in older adults. Aging Clinical and Experimental Research, 30(8), 921-925. doi:10.1007/s40520-017-0878-5

Razak, A. H., Zayegh, A., Begg, R. K., & Wahab, Y. (2012). Foot plantar pressure measurement system: a review. Sensors (Basel), 12(7), 9884-9912. doi:10.3390/s120709884

Ritt, M., Jager, J., Ritt, J., Sieber, C., & Gassmann, K. G. (2017). Analysis of a Frailty Index based on Routine Blood / Urine Parameters (FI-LAB) as a Frailty Screening Tool in inpatient geriatric Patients. Zeitschrift Fur Gerontologie Und Geriatrie, 50, S4-S4.

Ritt, M., Ritt, J. I., Sieber, C. C., & Gassmann, K. G. (2017). Comparing the predictive accuracy of frailty, comorbidity, and disability for mortality: a 1-year follow-up in patients hospitalized in geriatric wards. Clinical Interventions in Aging, 12, 293-304. doi:10.2147/Cia.S124342

Robinson, C. C., Balbinot, L. F., Silva, M. F., Achaval, M., & Zaro, M. A. (2013). Plantar pressure distribution patterns of individuals with prediabetes in comparison with healthy individuals and individuals with diabetes. J Diabetes Sci Technol, 7(5), 1113-1121. doi:10.1177/193229681300700503

Rubenstein, L. Z., Josephson, K. R., Trueblood, P. R., Loy, S., Harker, J. O., Pietruszka, F. M., & Robbins, A. S. (2000). Effects of a group exercise program on strength, mobility, and falls among fall-prone elderly men. J Gerontol A Biol Sci Med Sci, 55(6), M317-321. doi:10.1093/gerona/55.6.m317

Salzman, B., Wynn, D., Alabi, T., DeJoseph, D., & Seraj, S. (2010). Survey of Falls-Screening Practices among Primary Care Providers in an Outpatient Setting. Journal of the American Geriatrics Society, 58, 46-47.

Schwenk, M., Zieschang, T., Englert, S., Grewal, G., Najafi, B., & Hauer, K. (2014). Improvements in gait characteristics after intensive resistance and functional training in people with dementia: a randomised controlled trial. Bmc Geriatrics, 14. doi:Artn 7310.1186/1471-2318-14-73

Scott, G., Menz, H. B., & Newcombe, L. (2007). Age-related differences in foot structure and function. Gait & Posture, 26(1), 68-75. doi:10.1016/j.gaitpost.2006.07.009

Shumway-Cook, A., Ciol, M. A., Hoffman, J., Dudgeon, B. J., Yorkston, K., & Chan, L. (2009). Falls in the Medicare Population: Incidence, Associated Factors, and Impact on Health Care. Physical Therapy, 89(4), 324-332. doi:10.2522/ptj.20070107

Simmonds, M. J., Lee, C. E., Etnyre, B. R., & Morris, G. S. (2012). The influence of pain distribution on walking velocity and horizontal ground reaction forces in patients with low back pain. Pain Res Treat, 2012, 214980. doi:10.1155/2012/214980

Sole, G., Pataky, T., Sole, C. C., Hale, L., & Milosavljevic, S. (2017). Age-related plantar centre of pressure trajectory changes during barefoot walking. Gait & Posture, 57, 188-192. doi:10.1016/j.gaitpost.2017.06.016

Springer, S., Giladi, N., Peretz, C., Yogev, G., Simon, E. S., & Hausdorff, J. M. (2006). Dual-tasking effects on gait variability: The role of aging, falls, and executive function. Movement Disorders, 21(7), 950-957. doi:10.1002/mds.20848

Stegemoller, E. L., Wilson, J. P., Hazamy, A., Shelley, M. C., Okun, M. S., Altmann, L. J. P., & Hass, C. J. (2014). Associations Between Cognitive and Gait Performance During Single- and Dual-Task Walking in People With Parkinson Disease. Physical Therapy, 94(6), 757-766. doi:10.2522/ptj.20130251

Studenski, S., Perera, S., Patel, K., Rosano, C., Faulkner, K., Inzitari, M., . . . Guralnik, J. (2011). Gait Speed and Survival in Older Adults. Jama-Journal of the American Medical Association, 305(1), 50-58. doi:DOI 10.1001/jama.2010.1923

Sullivan, J., Burns, J., Adams, R., Pappas, E., & Crosbie, J. (2015). Plantar heel pain and foot loading during normal walking. Gait & Posture, 41(2), 688-693. doi:10.1016/j.gaitpost.2015.01.025

Tak, E., Kuiper, R., Chorus, A., & Hopman-Rock, M. (2013). Prevention of onset and progression of basic ADL disability by physical activity in community dwelling older adults: A meta-analysis. Aging Research Reviews, 12(1), 329-338. doi:10.1016/j.arr.2012.10.001

Thaler-Kall, K., Peters, A., Thorand, B., Grill, E., Autenrieth, C. S., Horsch, A., & Meisinger, C. (2015). Description of spatio-temporal gait parameters in elderly people and their association with history of falls: results of the population-based cross-sectional KORA-Age study. Bmc Geriatrics, 15. doi:ARTN 3210.1186/s12877-015-0032-1

Thingstad, P., Egerton, T., Ihlen, E. F., Taraldsen, K., Moe-Nilssen, R., & Helbostad, J. L. (2015). Identification of gait domains and key gait variables following hip fracture. Bmc Geriatrics, 15. doi:ARTN 15010.1186/s12877-015-0147-4

Thune-Boyle, I. C. V., Iliffe, S., Cerga-Pashoja, A., Lowery, D., & Warner, J. (2012). The effect of exercise on behavioral and psychological symptoms of dementia: towards a research agenda. International Psychogeriatrics, 24(7), 1046-1057. doi:10.1017/S1041610211002365

Toebes, M. J. P., Hoozemans, M. J. M., Furrer, R., Dekker, J., & van Dieen, J. H. (2015). Associations between measures of gait stability, leg strength and fear of falling. Gait & Posture, 41(1), 76-80. doi:10.1016/j.gaitpost.2014.08.015

Tseng, C. N., Gau, B. S., & Lou, M. F. (2011). The Effectiveness of Exercise on Improving Cognitive Function in Older People: A Systematic Review. Journal of Nursing Research, 19(2), 119-130. doi:10.1097/JNR.0b013e3182198837

Van Abbema, R., De Greef, M., Craje, C., Krijnen, W., Hobbelen, H., & Van Der Schans, C. (2015). What type, or combination of exercise can improve preferred gait speed in older adults? A meta-analysis. Bmc Geriatrics, 15, 72. doi:10.1186/s12877-015-0061-9 van Het Reve, E., Silveira, P., Daniel, F., Casati, F., & de Bruin, E. D. (2014). Tablet-based strength-balance training to motivate and improve adherence to exercise in independently living older people: part 2 of a phase II preclinical exploratory trial. Journal of Medical Internet Research, 16(6), e159. doi:10.2196/jmir.3055

Vermeulen, J., Neyens, J. C. L., van Rossum, E., Spreeuwenberg, M. D., & de Witte, L. P. (2011). Predicting ADL disability in community-dwelling elderly people using physical frailty indicators: a systematic review. Bmc Geriatrics, 11. doi:Artn 3310.1186/1471-2318-11-33

Wong-Yu, I. S., & Mak, M. K. (2015). Task- and Context-Specific Balance Training Program Enhances Dynamic Balance and Functional Performance in Parkinsonian Nonfallers: A Randomized Controlled Trial With Six-Month Follow-Up. Archives of Physical Medicine and Rehabilitation, 96(12), 2103-2111. doi:10.1016/j.apmr.2015.08.409

Wonneberger, M., & Schmidt, S. (2015). Changes of gait parameters following long-term aerobic endurance exercise in mildly disabled multiple sclerosis patients: an exploratory study. European Journal of Physical and Rehabilitation Medicine, 51(6), 755-762.

4. Community-Based Exercise Intervention for Gait and Functional Fitness Improvement in an Older Population - Protocol Study[2]

4.1. Abstract

Functional fitness (FF) and gait ability in older populations have been associated with increased survival rates, fall prevention and quality of life. One possible intervention for the improvement of FF is well-structured exercise programs. However, there are inconsistent findings regarding the effects of exercise interventions in the maintenance of gait parameters. The aim of this protocol is to develop a community-based exercise intervention targeting an older population. The intervention aim is the improvement of gait parameters and FF. A control trial with follow-up will be performed. The primary outcome variables will be the gait parameters related to plantar pressure. The secondary outcome variables will be aerobic endurance, lower limb strength, agility, and balance. These variables will be recorded at baseline and after 12, 24 and 36 weeks, in the intervention and control groups. If effective, this protocol can be used by exercise professionals in improving community exercise programs.

4.2. Background

There is a global imperative to awareness of the emerging evidence on physical activity (PA) among older adults. “Healthy aging” has traditionally focused on prevention disease, but greater efforts are needed to reduce frailty and dependency and maintain independent physical and cognitive function among older adults (Bauman et al., 2016).

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[2] Published as:
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Maintaining functional status is an important part of active aging and reducing age-related morbidity; it facilitates independent living, improves the quality of life, and reduces health care costs (Chodzko-Zajko et al., 2009; Nelson et al., 2007). A systematic review concluded that PA reduces the age-related decline in functional capacity and maintains muscle strength and mass among adults aged 65–85 years (Paterson & Warburton, 2010). A 50% reduction in the relative risk of developing functional limitations or disability was reported among those participating in moderate-intensity PA (Paterson & Warburton, 2010; Tak et al., 2013). Among older groups (aged 70–75 years), the functional status may be preserved with even lower amounts of PA. It remains less clear whether progressive resistance training alone can influence functional performance, although Liu and Latham (2009) reported significant independent effects of resistance training on strength and on the capacity to perform activities of daily living. Initially, interventions were mostly based in community centers. The proportion of home-based interventions increased over time; for example, in the review by Chase (2015) covering the period 2000–2012, half of the interventions were home based. The PA targets in early reviews mostly focused on planned (structured) sessions of aerobic activity or muscle strengthening; fewer involved multimodal activities, such as balance or functional capacities (King et al., 1998; van der Bij et al., 2002). Importantly, the effects of moderate-intensity and prescribed exercise were stronger than interventions that promoted low-intensity PA or had no prescription. The superiority of center- versus home-based approach have also been discussed, and were inconsistent (Chase, 2015; van der Bij et al., 2002), favoring the center-intervention, however without controlling for the duration interventions (Conn et al., 2002). The majority of interventions reviewed were short-term (<6 months), and the differences between these two approaches were small, yet in “real world” settings, there is a substantial decline in attendance at center-based classes for seniors (Nancy et al., 1998; van der Bij et al., 2002).

There is consistent literature regarding the impact of exercise programs on functional fitness parameters, despite the heterogeneity of the interventions and the fact that most of the studies are focused on clinical populations (Chen et al., 2015; Conn, 2010; Liu et al., 2011; Parmenter et al., 2011; Rubenstein et al., 2000; Thune-Boyle et al., 2012; Tseng et al., 2011). Gait variability and speed could be helpful in identifying different categories of frailty, despite the paucity of studies (Schwenk et al., 2014). However, the literature is not consistent in what is concerned with the effect of exercise on the maintenance of gait attributes in older people. Significant positive meta-effect of different types of exercise interventions from randomized controlled trials have been shown to improvement in preferred gait speed (Van Abbema et al., 2015) and dual-task walking in older adults (Plummer et al., 2015). Moreover, walking-based exercise may contribute to improved gait parameters (step cadence and length) in multiple sclerosis patients (Wonneberger & Schmidt, 2015).

Nevertheless, there are inconsistent findings in clinical trials regarding the effects of exercise on the other gait parameters, such as the kinetic variables representative of biomechanical loading. The information derived from plantar pressure measures is important in gait and posture research for diagnosing lower limb problems and injury prevention (Amemiya et al., 2014; Lee et al., 2007; Razak et al., 2012; Robinson et al., 2013), among other applications, such as analyzing the effects of a treatment or intervention (Chen et al., 2015; Iunes et al., 2014; Parkatti et al., 2012).

The challenge is now to know, how should be the design of a consistent community exercise program exercise program in order to promote physical independence and improvement of mobility pattern in older adults who lives in the community. In this study it will purpose the developed an intervention program that integrates the concept of multi-component exercises, tailored to the functional capacity level of each participant and organized in a group-based setting, aimed at improving the functional fitness and gait attributes, in a group of community living older people. The intervention to be tested in our trial is based on a periodized and controlled physical exercise program, based on the following components: (1) posture control, (2) balance (static and dynamic), (3) strength e agility of lower limbs, and (4) aerobic capacity.

We hypothesized that these 9 months intervention will be effective for the improvement of the gait and functional fitness parameters of older participants. Moreover, we hypothesized that this intervention will be more effective than a usual exercise program. The present study protocol describes the rationale, the design and the methods of the “More Active Aging Program” (MAAP), as well as the test procedures, from baseline to three, six and nine months of intervention.

4.3. Purposes

The aim of this protocol is to develop a community-based exercise intervention targeting an older population. The aim of the intervention is the improvement of gait and functional fitness parameters.

4.4. Participants and Methods

4.4.1. Design

The approach to the proposed study includes a 9 months follow-up intervention designed to test the effectiveness of a periodized and controlled exercise program effects on the gait and functional fitness parameters. The study will use a multicenter approach (Figure 6). An intervention group will receive a three-phased intervention with follow-up. Phase I (first cycle of 12 weeks) is characterized by the development of postural control and balance; Phase II (13 to 24 weeks) is focused on strength and muscle resistance improvement in lower limbs; and Phase III (25 to 36 weeks) is branded by the development of the fitness components in a more autonomous way. Other groups of older people (control group) will receive a non-periodized intervention with follow-up. The intervention will be carried out for 36 weeks, twice a week, for 50 min each session. The follow-up period will be 12, 24 and 36 weeks from the baseline condition.

The study will be conducted in partnership with the Sport Sciences School of Rio Maior – Polytechnic Institute of Santarém and the Neuromechanics of Human Movement Research Group of CIPER/Faculdade de Motricidade Humana, Universidade de Lisboa. This study received ethical approval by the Ethics Committee of the Faculty of Human Kinetics, University of Lisbon. A written informed consent will be obtained from all participants at the beginning of the intervention, before the allocation to the two groups (intervention or control groups).

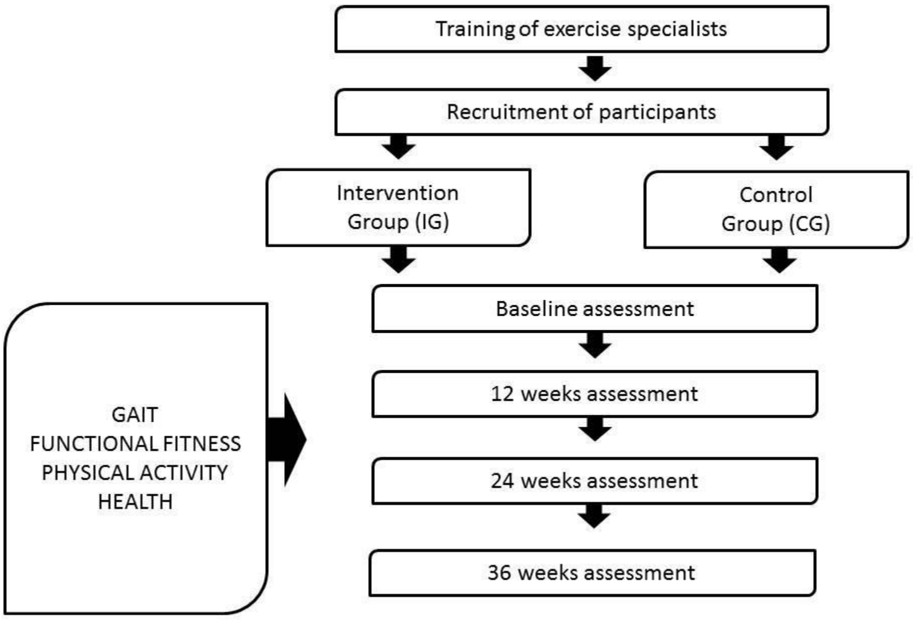

Figure 6. Phases of the study

4.4.2. Intervention planning

Graduated exercise specialists will deliver all exercise sessions, and will use the same planning on all subgroup classes, in accordance with the recommendations of the American College of Sports Medicine (ACSM, 2013). After agreeing in taking part of the staff, the exercise specialists will attend to a 20h training program. This training is focused on the pedagogical aspects of each stage of the program, as well as on the assessment procedures.

The recruitment planning processes will be developed by means of direct contact, brochures and municipalities' website. Regarding participant's recruitment, any person who meets the inclusion criteria will be invited to participate in one of the community centers without any payment. The project manager will explain the objectives of the study and answer all questions before asking the participant to consent the participation in the study.

This planning will allow the follow-up record of complete data on the participants of both groups (intervention and control), as well as, analyzes and comparisons of changes in the variables mentioned above.

4.4.3. Setting

The intervention will be implemented in community centers, among people aged 65 years or older, who live in five municipalities of West and Ribatejo regions of Portugal. Six community centers will be offering an exercise program. The MAAP will be implemented in three of these centers. The control group will be attending to an exercise program in the other three settings. The project manager will check the conditions of the locations, regarding the available equipment and safety. The project manager will check the conditions of the locations, regarding the available equipment and safety.

4.4.4. Participants

The older adults will be engaged in the MAAP through the sports community services of the five municipalities and will include the population living in small towns and rural areas. The project manager will call participants who show interest in participating, will give a verbal description of the study, will explain the risks and benefits of participating, and will ask for medical clearance for physical exercise.

Participants will be considered eligible for the study if they are aged 65 years and older, community-dwelling living, understand the Portuguese language and agree to participate voluntarily in this study. The exclusion criteria will include: neurologic condition (e.g. dementia or Parkinson disease), cardiovascular condition (e.g. stroke), or other abnormality that would influence the ability to answer a questionnaire, neither speaking nor understanding the Portuguese language, use of a walking aid, presence of hip, knee or ankle prosthesis, or incapacity of performing exercises in the standing position. Participants will be randomly assigned to each intervention group (IG) or control group (CG) taking into account the geographical proximity of their homes and intervention settings, i.e., they will be given the opportunity to choose between, at least, two of the available settings. Both groups will include participants with similar characteristics regarding mean age, inclusion and exclusion criteria.

The calculation of the sample size is based on the detection of significant differences in individual's functional fitness score (over 3, 6 and 9 months) in MAAP group when compared to other exercise program group (CG). In order to detect a minimum effect size of 0.50, with power (1-B) set as 0.80 and alpha set at 0.05, 174 participants will be recruited from six regional centers. Assuming that this will be an intervention study with a loss to follow-up of 10%, the sample size will be 191 participants.

The loss to follow-up will be calculated from the proportion of participants that will be randomly assigned to the intervention (n=96) and control groups (n=95) (Dettori, 2011).

Moreover, it will be excluded from the analysis, participants with an attendance rate lower than 75% of the sessions in each of the cycles of the program.

4.4.5. Exercise Program

Our program was designed to focus specifically the postural stability, balance and strength in lower limbs, combined with aerobic exercise, at a level of intensity in accordance with the participants' functional capacities.

Balance and strength are two of the components of functional fitness, and have been related to physical risk factors related to falls (Carter et al., 2001; McInnes et al., 2005; Panel on Prevention of Falls in Older Persons & British Geriatrics, 2011; Rose & Hernandez, 2010; Shekelle et al., 2003; Sherrington et al., 2011; Skelton & Beyer, 2003). In this regard, Rose and Hernandez (2010) emphasize the specific relevance of incorporating multiple dimensions of balance in exercise sessions, using movements that challenge stability in standing positions and activities designed to improve sensory processing and integration, attention capacity and coordination.

Regarding strength training, the relationship between its effects on fall prevention is not clear, despite the fact that muscle weakness in lower limbs is considered one of the most important fall risk factors ([no authors listed], 2001; Carter et al., 2001). This can be explained by the fact that the long-term benefits of strength training in the prevention of falls are not evident in trials with follow-ups of short duration (Sherrington et al., 2011). Nevertheless, the inclusion of strength and power training in lower limbs is recommended (ACSM, 2013; Rose & Hernandez, 2010; Skelton et al., 1994) given its role in the mechanical efficiency of gait and relationship to functional tasks such as step climbing and obstacle crossing (McInnes et al., 2005).

These components (posture stability, balance and strength training) will be based on group exercise and circuit training. The aerobic component will be based on walking and mobility group exercise.

The intervention group (IG) will be engaged in an exercise program that will be controlled, periodized and organized in three cycles of 12 weeks, according to the structure presented in Table 4.

The IG exercise program will follow a linear periodization to provide weekly progressive modifications in intensity and complexity, and to change the type of exercises monthly, considering the pre-defined objectives for each part of the session, based on the training principles of overload, progression, and variability (Bompa & Haff, 2009). Each exercise should be specifically designed to have alternative options to the participants' limitations (e.g. difficulties to perform an exercise in kneeling or lying position), and to evolve from the functional fitness level of the participants. Monthly checklists will be created to confirm if the target goals defined for each type of exercise (postural control, balance, and strength) are being achieved according to the predefined program. With these checklists, instructors should verify the percentage of participants who correctly performed the exercises and then report the results to the researchers, to make the necessary adjustments in planning.

Table 4. Structure of the exercise program of the intervention group

Phase and period	Aims, pattern and frequency	Features
Phase I (1 to 12 weeks)	Development of postural alignment and balance (static and dynamic). Pattern: sessions based on group exercise, including warm-up (5 min) and cool-down (5 min). Frequency: two sessions/week	Type: Aerobic exercise - mobility exercises of the lower limb and walking pattern training with a gradual increase in intensity and complexity, but not imposing excessive orthopedic stress. Duration: 20 min Intensity: 3-4 Borg Scale Progression: 4-5 Borg Scale
		Type: Postural alignment - exercise routines, following postural and Pilates-based techniques will be used to develop body awareness, breathing patterns control, core muscles conditioning integrated with upper and lower limbs coordination performed in different body positions (lying down sitting and cat position). Duration: 10 min
		Type: Balance – sets of exercises performed in the standing position and based on functional training and Tai Chi techniques with controlled steps and weight shifts, progressing from stable to less stable base of support, in order to improve the center of mass control. Duration: 10 min
Phase II (13 to 24 weeks)	Improvement of strength and muscle resistance in lower limbs. Pattern: sessions based on group exercise and interval training, including warm-up (5 min) and cool-down (5 min). Frequency: two sessions/week	Type: Aerobic exercise - mobility exercises of the lower limb and walking pattern training with a gradual increase in intensity and complexity, but not imposing excessive orthopedic stress. Duration: 20 min Intensity: 4-5 Borg Scale Progression: 5-6 Borg Scale
		Type: Strength and muscle resistance in lower limbs, and core stability - using exercises with additional loads and elastic resistance as well as movements that progressively increase support instability and the integration of whole body movements (upper and lower limbs, together with core stability). Duration: 10 min Intensity: 10-15 repetitions (strength) / 15-20 repetitions (muscular endurance); 2 sets Progression: greater resistance and set of repetitions
		Type: Dynamic Balance – sets of exercises performed using dynamic positions such as changing direction, velocity, and planes of movement, and functional training, in order to improve the center of mass control. Duration: 10 min
Phase III (25 to 36 weeks)	Maintenance of fitness components and the integration of whole body movements (upper and lower limbs, together with core stability). . Pattern: sessions based on circuit training, including warm-up (5 min) and cool-down (5 min). Frequency: two sessions/week	Type: Aerobic exercise - mobility exercises of the lower limb and walking pattern training with a gradual increase in intensity and complexity, but not imposing excessive orthopedic stress. Duration: 20 min Intensity: 4-5 Borg Scale Progression: 5-6 Borg Scale
		Type: Strength and muscle resistance in lower limbs, and core stability - using exercises with additional loads and elastic resistance as well as movements that progressively increase support instability and the integration of whole body movements (upper and lower limbs, together with core stability). Duration: 10 min Intensity: 10-15 repetitions (strength) / 15-20 repetitions (muscular endurance); 2-3 sets Progression: greater resistance and set of repetitions
		Type: Dynamic Balance – sets of exercises performed using dynamic positions such as changing direction, velocity, and planes of movement, and functional training, in order to improve the center of mass control. Duration: 5 min
		Type: Flexibility will also be integrated into training programs, aimed at the maintenance or improvement of the joint mobility within the healthy limits. Duration: 5 min Intensity: static stretch to the point of feeling slight discomfort; hold a stretch for 30-60 s.

The control group (CG) will be engaged in an exercise program described in Table 5.

Table 5. Structure of the exercise program of the control group

Period	Aims, pattern and frequency	Features
(1 to 36 weeks)	Development and maintenance of fitness components and the integration of whole body movements Pattern: sessions based on group exercise, including warm-up (5 min) and cool-down (5 min). Frequency: two sessions/week	Type: Aerobic exercise - mobility exercises of the lower limb and walking pattern training with a gradual increase in intensity and complexity, but not imposing excessive orthopedic stress. Duration: 25 min Intensity: 3-4 Borg Scale Progression: 4-5 Borg Scale
		Type: Strength and muscle resistance in lower limbs, and core stability - using exercises with additional loads and elastic resistance as well as movements that progressively increase support instability and the integration of whole body movements (upper and lower limbs, together with core stability). Duration: 15 min Intensity: 10-15 repetitions (strength) / 15-20 repetitions (muscular endurance); 2-3 sets Progression: greater resistance and set of repetitions

The main difference between the CG and the IG programs are: planning and organization (periodization); the specificity of goals of the first 12 weeks (postural alignment and balance) and phase II; and the class design during phase 3 (circuit training) and its aim.

Both programs will last 36 weeks and will comprise group-based 50 min exercise sessions twice a week. Also, they will be delivered by different instructors. In both programs, the exercise intensity will be controlled by using the Borg Rate of Perceived Exertion (Borg CR-10 RPE) scale and participants will be encouraged to exercise at a level that they felt 4 (somewhat hard) to 6 (hard) (Day et al., 2004).

The participation of all subjects (IG and CG) will be controlled through attendance forms. The integrity of the intervention will be assessed by observation of two randomly selected sessions per month. The project manager will use a checklist to score sessions based on content identified in the intervention protocol. Drift will be defined as teaching less than 80% of the protocol content. If drift occurs, the examiner will be re-trained until the protocol is followed consistently. A checklist of behavioral indicators will be used to assess the examiner’s skills in facilitating sessions, engaging the participants, problem-solving, providing positive feedback, and goal setting. Retraining will be provided as necessary.

4.4.6. Plantar Pressure Gait Assessment

Key plantar pressure parameters will be recorded as subjects walked barefoot across a 10 m walkway placed on the floor, at self-determined velocity. The subjects will be allowed to acclimatize to the equipment by performing few steps before data collection. Five strides from each participant will be collected. Plantar pressure data will be obtained using a Novel emed-x system (Münich, Germany). The primary outcome variables will be the gait parameters that are described in table 3. Data will be collected using a high sensor resolution mode with a sensor resolution of 4 sensors/cm^2 and a frame rate of 100 Hz. The Novel software will be used for data analysis. Force data will be normalized to the body weight (BW) allowing comparisons. To our knowledge, there is no other study which has investigated the usefulness of these data as a measure of the effect of an exercise intervention in an independent older population.

4.4.7. Functional Fitness Assessment

Functional Fitness (FF) tests (Rikli & Jones, 1999) will be administered by trained examiners after engaging in a training workshop which previously demonstrated a high inter-observer agreement for all FF tests (Moniz-Pereira et al., 2012).

Three tests from the “Senior Fitness Tests” (SFT) battery (Rikli & Jones, 1999; Rikli & Jones, 2013) will be used to assess strength and mobility variables. Both dynamic and static balance will be evaluated through two tests each, from “Fullerton Advanced Balance Scale” (Rose et al., 2006). A total balance score (BTS) will be computed by the sum of the results from dynamic and static balance. The outcome measure Total Functional Fitness Score (TFFS) is a composite variable which can provide a comprehensive overview of the effects of this intervention (since it reflects the most important physical parameters related to intrinsic risk factors for falls in older people). Those tests have shown to be good predictors of falls and functional decline in community-living older adults (Hernandez & Rose, 2008; Rose, 2010; Rose et al., 2006; Sherrington et al., 2011). The secondary variables are described in Table 6.

Table 6. Primary and secondary outcome variables and covariables

Primary Outcome Variables	
Gait parameters	• Applied local force-maximum vertical ground reaction force (GRF); • Total force in an anatomical foot area (TOF); • Maximum and mean applied local pressure (PPM and PPm); • Pressure-time integral (PTI); • Force-time integral in an anatomical area (FTI); • Force-time integral timing of foot loading (TFL); • Impulse (IMP); • Deformation of the foot during loading (DFL).
Secondary Outcome Variables	
Performance tests	• "30s chair stand" (CS); • "8 foot up and go" (U&G); • "2-minute step" (2min).
Dynamic balance	• "Step up and over" (FAB4); • "Tandem walking" (FAB5).
Static balance	• "Stand on one leg" (FAB6); • "Stand on foam with eyes closed" (FAB7).
Covariables	
Health status and falls prevalence:	• Age; • Gender; • Scholarity; • Living alone • Health (HPS) self-perception status; • Medication intake (Meds); • Fear of falling (FOF); • Falls prevalence (FP).
Physical Activity:	• Vigorous activity; • Moderate level activity; • Time spent in sitting position; • Total time of PA.
Body composition:	• Body mass index.

4.4.8. Demographics, Health, and Physical Activity Assessment

The covariates will include: demographics, health and falls parameters, physical activity levels and body composition measures (Table 6).

Health status and falls prevalence will be assessed by a questionnaire designed and validated for Portuguese Language and Culture (Valente, 2012). The first part of the questionnaire includes questions about demographics. The second part is related to self-perception of health and falls. The history of falls was defined as the experience of any falls during the period before assessments (previous 12 months at baseline and three months during the follow-up period).

Physical activity (PA) profiles will also be evaluated by a short version of "Yale Physical Activity Survey" (YPAS) (Dipietro et al., 1993), which allows to define 6 distinct PA dimensions: 1)

Vigorous activity; 2) Leisurely walking; 3) Moving; 4) Standing; and 5) Sitting; and a PA total score, considering a typical week of the previous month. This questionnaire was validated for the Portuguese population (Machado et al., 2016).

Both questionnaires will be administered by face-to-face interviews involving the same trained examiners. The procedures are described elsewhere (Moniz-Pereira et al., 2012). Weight and height will be recorded to allow the calculation of body mass index (BMI).

4.4.9. Variables

The independent variables will be the features (type, duration, frequency, intensity and progression) of the exercise programs. The primary and secondary outcomes and the covariables that will be recorded before the intervention (baseline), and after 12, 24 and 36 weeks of intervention, in the intervention and control groups, are described in Table 6.

4.4.10. Data Management and Analysis

Participants will be tracked using ID numbers. All data will be entered by a researcher into a Statistical Package for Social Sciences (SPSS) database and backed up on a secure central computer network system. Data will undergo range, consistency, and outlier checks.

Statistical analysis will be performed to obtain descriptive statistics and to evaluate the effectiveness of the MAAP on the improvement of functional fitness status and mobility in the intervention group when compared to the program ministered to control group. Data normality distribution will be checked with the Kolmogorov-Smirnov test. Independent sample t-tests will be performed to compare continuous outcomes between groups (IG versus CG). Chi-square Test will be used for demographics and covariables with nominal classification. Repeated Measures two-way analysis of variance (ANOVA) (2X3) with Huynh-Feldt correction will be performed to: 1) analyze the longitudinal changes within each group, primary and secondary outcomes, and 2) to test the main effects of the intervention period (baseline to 12/24/36 weeks) and group interactions (IG versus CG) on the same outcomes. Polynomial contrasts will be used to verify linear and quadratic trends in reported changes. Significant interactions will be examined using single contrasts (first) to determine if effects are greater in the intervention or control group. The models will be design adjusted for covariables effects. Data will be analyzed using the SPSS (version 3.0) and statistical significance will be set at p <.05.

4.5. Discussion

This study aims to describe the rationale, the design and methods of the “More Active Aging Program”. The aim of the program is the improvement of gait and functional fitness parameters. We hypothesized that a well-periodized community program, in terms of the type of exercise and intensity progression, will have significantly better results in the improvement of gait and functional fitness parameters in the older population.

The study will provide insight of the efficacy of a 36-week intervention, and the results of the study will provide crucial information on the feasibility of delivering the intervention to the older population. Moreover, the exercise program is safe and targeted to the physical fitness levels and limitations of the participants, suggesting its usefulness as a means of health promotion among older populations.

The long-term effectiveness of this intervention will be established at the level of general mobility by means of adopting an active lifestyle, which can be translated into long-term effects in prevention of falls (Gillespie et al., 2012). In addition, this intervention aims to transfer these gains to the functional and independent living and may result in an improved impact on participants' quality of life, and lower public health costs. If it shows any benefit, this protocol can be promoted in clinical practice and can be indicated as a complementary treatment for functional decline. Moreover, if effective in slowing functional decline, this protocol can be used by exercise professionals in improving community exercise programs.

The potential limitations of this study might be the difficulties of randomization of the groups since older people will be keener on participating in the program in a more convenient setting (i.e. not far from home). In addition, the fitness instructors of the CG will not be blind to the objectives of the intervention, thus, they may give some emphasis on balance training and, therefore, promote the development of this capacity as in the intervention group. The time-consuming events related to the assessment of different variables will require extra time and planning, in addition to other activities related to the exercise program, requiring the attendance of the participants.

Regarding the strengths of the study, we highlight the ecological perspective to be used. Community group-based classes using multiple component exercises are the most popular programs attended by older people and provide health and psychosocial benefits which may contribute to compliance and long-term maintenance. The major strength of this study will be the development and implementation of an exercise program, combining the advantages of a community group program with the efficacy of controlled and periodized exercise and a progressive stimulus tailored to participant's functional fitness level and musculoskeletal limitations. Although the evidence of its efficacy in fall prevention is promising, it remains unclear which specific features (i.e. type, intensity, frequency, duration and progression) are needed so that these programs can be effective in the improvement of functional fitness and gait parameters, and consequently, on the reduction of risk of falling in the long term (Rose & Hernandez, 2010; Skelton & Beyer, 2003). On the other hand, it has been shown that long-term benefits are not evident in trials of short duration (Sherrington et al., 2011). Herein, we present a more comprehensive, more specific and long duration, exercise intervention for gait and functional fitness improvement in an older population, by periodizing selected postural, balance, strength and walking tasks, focusing on group exercise and circuit training.

Besides increased body weight (Butterworth et al., 2014), other factors have been associated with high levels of plantar pressure generated during gait (i.e. peak pressure and pressure-time integral), such as foot structure (O'Brien & Tyndyk, 2014), foot pain and risk of falls (Mickle et al., 2010), and walking strategy (Sullivan et al., 2015). If one limitation of an extensive biomechanical analysis is the requirement of expensive laboratory equipment, in this case, the existing portable equipment to collect force data can be used in the same setting where the exercise intervention and the other assessment take place.

We reinforce one of the strengths of the study which is the ecological perspective to be used. The intervention will be adapted to the typical community-based programs offered in rural areas and small towns to the older population.

4.6. References

[no authors listed]. (2001). Guideline for the prevention of falls in older persons. American Geriatrics Society, British Geriatrics Society, and American Academy of Orthopaedic Surgeons Panel on Falls Prevention. J Am Geriatr Soc, 49(5), 664-672.

ACSM. (2013). ACSM Guidelines for Exercise Testing and Exercise Prescription (9th ed.). Philadelphia: Wolters Kluwer/ Lippincott, Williams and Wilkins.

Amemiya, A., Noguchi, H., Oe, M., Ohashi, Y., Ueki, K., Kadowaki, T., . . . Sanada, H. (2014). Elevated plantar pressure in diabetic patients and its relationship with their gait features. Gait & Posture, 40(3), 408-414. doi:10.1016/j.gaitpost.2014.05.063

Bauman, A., Merom, D., Bull, F. C., Buchner, D. M., & Fiatarone Singh, M. A. (2016). Updating the Evidence for Physical Activity: Summative Reviews of the Epidemiological Evidence, Prevalence, and Interventions to Promote "Active Aging". Gerontologist, 56 Suppl 2, S268-280. doi:10.1093/geront/gnw031

Bompa, T. O., & Haff, G. (2009). Periodization : theory and methodology of training (5th ed.). Champaign, IL.: Human Kinetics.

Butterworth, P. A., Landorf, K. B., Gilleard, W., Urquhart, D. M., & Menz, H. B. (2014). The association between body composition and foot structure and function: a systematic review. Obesity Reviews, 15(4), 348-357. doi:10.1111/obr.12130

Carter, N. D., Kannus, P., & Khan, K. M. (2001). Exercise in the prevention of falls in older people: a systematic literature review examining the rationale and the evidence. Sports Med, 31(6), 427-438. doi:10.2165/00007256-200131060-00003

Chase, J. A. (2015). Interventions to Increase Physical Activity Among Older Adults: A Meta-Analysis. Gerontologist, 55(4), 706-718. doi:10.1093/geront/gnu090

Chen, M. S., Lin, T. C., & Jiang, B. C. (2015). Aerobic and resistance exercise training program intervention for enhancing gait function in elderly and chronically ill Taiwanese patients. Public Health, 129(8), 1114-1124. doi:10.1016/j.puhe.2015.04.018

Chodzko-Zajko, W. J., Proctor, D. N., Singh, M. A. F., Minson, C. T., Nigg, C. R., Salem, G. J., & Skinner, J. S. (2009). Exercise and Physical Activity for Older Adults. Medicine and Science in Sports and Exercise, 41(7), 1510-1530. doi:10.1249/MSS.0b013e3181a0c95c

Conn, V. S. (2010). Anxiety Outcomes After Physical Activity Interventions Meta-Analysis Findings. Nursing Research, 59(3), 224-231. doi:10.1097/NNR.0b013e3181dbb2f8

Conn, V. S., Valentine, J. C., & Cooper, H. M. (2002). Interventions to increase physical activity among aging adults: a meta-analysis. Ann Behav Med, 24(3), 190-200. doi:10.1207/s15324796abm2403_04

Day, M. L., McGuigan, M. R., Brice, G., & Foster, C. (2004). Monitoring exercise intensity during resistance training using the session RPE scale. J Strength Cond Res, 18(2), 353-358. doi:10.1519/r-13113.1

Dettori, J. R. (2011). Loss to follow-up. Evid Based Spine Care J, 2(1), 7-10. doi:10.1055/s-0030-1267080

Dipietro, L., Caspersen, C. J., Ostfeld, A. M., & Nadel, E. R. (1993). A survey for assessing physical activity among older adults. Med Sci Sports Exerc, 25(5), 628-642.

Gillespie, L. D., Robertson, M. C., Gillespie, W. J., Sherrington, C., Gates, S., Clemson, L. M., & Lamb, S. E. (2012). Interventions for preventing falls in older people living in the community. Cochrane Database Syst Rev(9), Cd007146. doi:10.1002/14651858.CD007146.pub3

Hernandez, D., & Rose, D. J. (2008). Predicting which older adults will or will not fall using the Fullerton Advanced Balance scale. Arch Phys Med Rehabil, 89(12), 2309-2315. doi:10.1016/j.apmr.2008.05.020

Iunes, D. H., Rocha, C. B., Borges, N. C., Marcon, C. O., Pereira, V. M., & Carvalho, L. C. (2014). Self-care associated with home exercises in patients with type 2 diabetes mellitus. Plos One, 9(12), e114151. doi:10.1371/journal.pone.0114151

King, P. M., Tuckwell, N., & Barrett, T. E. (1998). A critical review of functional capacity evaluations. Physical Therapy, 78(8), 852-866. doi:10.1093/ptj/78.8.852

Lee, M. Y., Lin, C. F., & Soon, K. S. (2007). New foot pressure activated sensory compensation system for posture-control enhancement in Amputees. Ieee-Asme Transactions on Mechatronics, 12(3), 236-243. doi:10.1109/Tmech.2007.897234

Liu, C. J., & Latham, N. K. (2009). Progressive resistance strength training for improving physical function in older adults. Cochrane Database Syst Rev(3), Cd002759. doi:10.1002/14651858.CD002759.pub2

Liu, Y. P., Hu, F. L., Li, D. D., Wang, F., Zhu, L., Chen, W. Y., . . . Zhao, Y. S. (2011). Does Physical Activity Reduce the Risk of Prostate Cancer? A Systematic Review and Meta-analysis. European Urology, 60(5), 1029-1044. doi:10.1016/j.eururo.2011.07.007

Machado, M., Tavares, C., Moniz-Pereira, V., André, H., Ramalho, F., Veloso, A., & Carnide, F. (2016). Validation of YPAS-PT – The Yale Physical Activity Survey for Portuguese Older People. Science Journal of Public Health, 4(1), 72-80. doi:10.11648/j.sjph.20160401.20

McInnes, L., Gibbons, E., & Chandler-Oatts, J. (2005). Clinical practice guideline for the assessment and prevention of falls in older people. Worldviews Evid Based Nurs, 2(1), 33-36. doi:10.1111/j.1524-475X.2005.04094.x

Mickle, K. J., Munro, B. J., Lord, S. R., Menz, H. B., & Steele, J. R. (2010). Foot Pain, Plantar Pressures, and Falls in Older People: A Prospective Study. Journal of the American Geriatrics Society, 58(10), 1936-1940. doi:10.1111/j.1532-5415.2010.03061.x

Moniz-Pereira, V., Carnide, F., Machado, M., Andre, H., & Veloso, A. P. (2012). Falls in Portuguese older people: procedures and preliminary results of the study Biomechanics of Locomotion in the Elderly. Acta Reumatologica Portuguesa, 37(4), 324-332.

Nancy, A. E., Anita, M. M., & Donald, H. P. (1998). Tracking Older Participants of Twelve Physical Activity Classes Over a Three-Year Period. Journal of Aging and Physical Activity, 6(1), 70-82. doi:10.1123/japa.6.1.70

Nelson, M. E., Rejeski, W. J., Blair, S. N., Duncan, P. W., Judge, J. O., King, A. C., . . . Castaneda-Sceppa, C. (2007). Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. Med Sci Sports Exerc, 39(8), 1435-1445. doi:10.1249/mss.0b013e3180616aa2

O'Brien, D. L., & Tyndyk, M. (2014). Effect of arch type and Body Mass Index on plantar pressure distribution during stance phase of gait. Acta Bioeng Biomech, 16(2), 131-135.

Panel on Prevention of Falls in Older Persons, A. G. S., & British Geriatrics, S. (2011). Summary of the Updated American Geriatrics Society/British Geriatrics Society clinical practice guideline for prevention of falls in older persons. J Am Geriatr Soc, 59(1), 148-157. doi:10.1111/j.1532-5415.2010.03234.x

Parkatti, T., Perttunen, J., & Wacker, P. (2012). Improvements in functional capacity from Nordic walking: a randomized-controlled trial among elderly people. J Aging Phys Act, 20(1), 93-105. doi:10.1123/japa.20.1.93

Parmenter, B. J., Raymond, J., Dinnen, P., & Singh, M. A. (2011). A systematic review of randomized controlled trials: Walking versus alternative exercise prescription as treatment for intermittent claudication. Atherosclerosis, 218(1), 1-12. doi:10.1016/j.atherosclerosis.2011.04.024

Paterson, D. H., & Warburton, D. E. (2010). Physical activity and functional limitations in older adults: a systematic review related to Canada's Physical Activity Guidelines. Int J Behav Nutr Phys Act, 7, 38. doi:10.1186/1479-5868-7-38

Plummer, P., Zukowski, L. A., Giuliani, C., Hall, A. M., & Zurakowski, D. (2015). Effects of Physical Exercise Interventions on Gait-Related Dual-Task Interference in Older Adults: A Systematic Review and Meta-Analysis. Gerontology, 62(1), 94-117. doi:10.1159/000371577

Razak, A. H., Zayegh, A., Begg, R. K., & Wahab, Y. (2012). Foot plantar pressure measurement system: a review. Sensors (Basel), 12(7), 9884-9912. doi:10.3390/s120709884

Rikli, R. E., & Jones, C. J. (1999). Functional fitness normative scores for community-residing older adults, ages 60-94. Journal of Aging and Physical Activity, 7(2), 162-181. doi:https://doi.org/10.1123/japa.7.2.162

Rikli, R. E., & Jones, C. J. (2013). Senior fitness test manual (2nd ed.). Champaign, IL: Human Kinetics.

Robinson, C. C., Balbinot, L. F., Silva, M. F., Achaval, M., & Zaro, M. A. (2013). Plantar pressure distribution patterns of individuals with prediabetes in comparison with healthy individuals and individuals with diabetes. J Diabetes Sci Technol, 7(5), 1113-1121. doi:10.1177/193229681300700503

Rose, D. J. (2010). Fallproof! : a comprehensive balance and mobility training program (2nd ed.). Champaign, IL: Human Kinetics.

Rose, D. J., & Hernandez, D. (2010). The role of exercise in fall prevention for older adults. Clin Geriatr Med, 26(4), 607-631. doi:10.1016/j.cger.2010.07.003

Rose, D. J., Lucchese, N., & Wiersma, L. D. (2006). Development of a Multidimensional Balance Scale for Use With Functionally Independent Older Adults. Archives of Physical Medicine and Rehabilitation, 87(11), 1478-1485. doi:10.1016/j.apmr.2006.07.263

Rubenstein, L. Z., Josephson, K. R., Trueblood, P. R., Loy, S., Harker, J. O., Pietruszka, F. M., & Robbins, A. S. (2000). Effects of a group exercise program on strength, mobility, and falls among fall-prone elderly men. J Gerontol A Biol Sci Med Sci, 55(6), M317-321. doi:10.1093/gerona/55.6.m317

Schwenk, M., Zieschang, T., Englert, S., Grewal, G., Najafi, B., & Hauer, K. (2014). Improvements in gait characteristics after intensive resistance and functional training in people with dementia: a randomised controlled trial. Bmc Geriatrics, 14. doi:Artn 7310.1186/1471-2318-14-73

Shekelle, P., Maglione, M., Chang, J., Mojica, W., Shekelle, P. G., Maglione, M. A., . . . Lapin, P. (2003). Falls Prevention Interventions in the Medicare Population. In.

Sherrington, C., Tiedemann, A., Fairhall, N., Close, J. C., & Lord, S. R. (2011). Exercise to prevent falls in older adults: an updated meta-analysis and best practice recommendations. N S W Public Health Bull, 22(3-4), 78-83. doi:10.1071/NB10056

Skelton, D. A., & Beyer, N. (2003). Exercise and injury prevention in older people. Scand J Med Sci Sports, 13(1), 77-85. doi:10.1034/j.1600-0838.2003.00300.x

Skelton, D. A., Greig, C. A., Davies, J. M., & Young, A. (1994). Strength, power and related functional ability of healthy people aged 65-89 years. Age Aging, 23(5), 371-377. doi:10.1093/aging/23.5.371

Sullivan, J., Burns, J., Adams, R., Pappas, E., & Crosbie, J. (2015). Plantar heel pain and foot loading during normal walking. Gait & Posture, 41(2), 688-693. doi:10.1016/j.gaitpost.2015.01.025

Tak, E., Kuiper, R., Chorus, A., & Hopman-Rock, M. (2013). Prevention of onset and progression of basic ADL disability by physical activity in community dwelling older adults: A meta-analysis. Aging Research Reviews, 12(1), 329-338. doi:10.1016/j.arr.2012.10.001

Thune-Boyle, I. C. V., Iliffe, S., Cerga-Pashoja, A., Lowery, D., & Warner, J. (2012). The effect of exercise on behavioral and psychological symptoms of dementia: towards a research agenda. International Psychogeriatrics, 24(7), 1046-1057. doi:10.1017/S1041610211002365

Tseng, C. N., Gau, B. S., & Lou, M. F. (2011). The Effectiveness of Exercise on Improving Cognitive Function in Older People: A Systematic Review. Journal of Nursing Research, 19(2), 119-130. doi:10.1097/JNR.0b013e3182198837

Valente, S. F. P. (2012). Validação de um questionário de saúde e identificação de factores de risco de quedas para a população idosa portuguesa. (Mestrado Dissertação de Mestrado), Universidade Técnica de Lisboa, Lisboa.

Van Abbema, R., De Greef, M., Craje, C., Krijnen, W., Hobbelen, H., & Van Der Schans, C. (2015). What type, or combination of exercise can improve preferred gait speed in older adults? A meta-analysis. Bmc Geriatrics, 15, 72. doi:10.1186/s12877-015-0061-9

van der Bij, A. K., Laurant, M. G., & Wensing, M. (2002). Effectiveness of physical activity interventions for older adults: a review. Am J Prev Med, 22(2), 120-133. doi:10.1016/s0749-3797(01)00413-5

Wonneberger, M., & Schmidt, S. (2015). Changes of gait parameters following long-term aerobic endurance exercise in mildly disabled multiple sclerosis patients: an exploratory study. European Journal of Physical and Rehabilitation Medicine, 51(6), 755-762.

5. Effect of 6-Month Community-Based Exercise Interventions on Gait and Functional Fitness of an Older Population - A Quasi-Experimental Study[3]

5.1. Abstract

Gait ability in older adults has been associated with independent living, increased survival rates, fall prevention and quality of life. There are inconsistent findings regarding the effects of exercise interventions in the maintenance of gait parameters. The aim of the study was to analyze the effects of a community-based periodized exercise intervention on the improvement of gait parameters and functional fitness in an older adults group when compared with a non-periodized program. A quasi-experimental study with follow-up was performed in a periodized exercise intervention group (N=15) and in a non-periodized exercise group (N=13). The primary outcomes were plantar pressure gait parameters. The secondary outcomes were physical activity, aerobic endurance, lower limb strength, agility, and balance. These variables were recorded at baseline and after 6 months of intervention. Both programs were tailored to older adults' functional fitness level and proved to be effective in reducing the age-related decline regarding functional fitness and gait parameters. Gait parameters were sensitive to both exercise interventions. These exercise protocols can be used by exercise professionals in prescribing community exercise programs, as well as by health professionals in promoting active aging.

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5.2. Background

Gait ability in older adults has been associated with increased survival rates, fall prevention and quality of life (Chodzko-Zajko et al. 2009; Nelson et al. 2007). The changes in the structure and function of the foot are associated with aging and have considerable implications for the well-being of the older adult (Menz (2015). Gait ability is related to mobility, which in turn, is a critical variable in maintaining independence in older adults (Chung et al. 2016). Furthermore, the functional status of older adults promotes independent living, improves the quality of life, and reduces health care costs (Chodzko-Zajko et al. 2009; Nelson et al. 2007). Moreover, gait variability and speed can also help in identifying different categories of frailty (Schwenk et al. 2014).

The information derived from podobarometric measures is important in gait and posture research for diagnosing lower limb problems and injury prevention (Lee et al. 2007; Razak et al. 2012; Robinson et al. 2013; Keijsers et al. 2013; Amemiya et al. 2014). Several factors have been associated with high levels of plantar pressure (i.e., peak pressure and pressure-time integral) generated during gait, such as increased body weight (Butterworth et al. 2014), foot structure (arch type) (O'Brien and Tyndyk 2014), foot pain and risk of falls (Mickle et al. 2010), active diabetic foot ulcers (Fernando et al. 2016) and walking strategy (Sullivan et al. 2015).

Exercise is considered a key intervention for improving physical function in older adults (Wang et al. 2015). It is well established in the literature that exercise programs reduce the age-related decline in functional capacity and maintain muscle strength and mass among adults aged 65–85 years (Paterson and Warburton 2010). It is expected 50% of reduction in the relative risk of developing functional limitations or disability was reported among those participating in a moderate-intensity physical activity (Paterson and Warburton 2010; Tak et al. 2013), as well as the improvement of functional fitness parameters (Chase 2015; Conn et al. 2002; Liu and Latham 2009; 2011; Seco et al. 2012).

Recently, Wonneberger and Schmidt (2015) suggested that a walking-based exercise may contribute to improve step cadence and step length in multiple sclerosis patients, and Wang et al. (2015) proved that short-term combined exercise improves gait performance in community-dwelling older adults. Different types of exercise interventions from randomized controlled trials have been shown to improve preferred gait speed (Van Abbema et al. 2015).

However, most studies were focused on clinical populations, and the heterogeneity of the interventions leads to inconsistent results on outcomes (Chen et al. 2015; Conn et al. 2002; Parmenter et al. 2011; Rubenstein et al. 2000). In particular, there is heterogeneity regarding the ways of defining and measuring gait ability in older adults, such as a performance-based test or usual gait speed (Chung et al. 2016). Foot loading data (plantar pressure and force) can be used to analyze the effects of a treatment or an exercise intervention (Parkatti et al. 2012; Iunes et al. 2014; Chen et al. 2015; Kim and Park 2015) since plantar pressure values present a consistent pattern in the elderly (Franco et al. 2015), and there is no age dependence of podobarometric data (Lalande et al. 2016). Nevertheless, the podobarometric effects of physical activity have rarely been investigated and reported in the literature. To the extent of our knowledge, the study developed by Monteiro et al. (2010) is the only to investigate the of a 12-month exercise program on podobarometric data in post-menopausal women, and proved that women who exercised have decreased loading of maximal peak pressures and absolute impulses.

Furthermore, although periodization is an important method for training organization in athletes, there is still a lack of evidence of its use in untrained adults (Strohacker et al. 2015). Considering the importance of gait ability for the independence and quality of life of older adults.

5.3. Objectives

The aim of the study was to analyze the effects of a community-based periodized exercise intervention on the improvement of gait parameters and functional fitness in an older adults group when compared with a non-periodized program.

We hypothesized that a 6-months community-based periodized exercise intervention would be more effective than a non-periodized one for the maintenance or improvement of the gait and functional fitness parameters of older participants.

5.4. Methods

5.4.1. Design

A quasi-experimental study was developed. The full protocol of the study is published elsewhere (Ramalho et al. 2017). A multi-component community-based exercise intervention, named “More Active Aging Program (MAAP), organized in a group-based setting was developed. The intervention group received a periodized intervention. The control group was committed to a non-periodized intervention. The intervention was carried out for 24 weeks, twice a week, for 50 min each session. We compared the MAAP (exercise group 1 = EG1) with other non-periodized program - NOPP (exercise group 2 = EG2) for older adults, also described in Ramalho et al. (2017).

The study was conducted in partnership with Sport Sciences School of Rio Maior from the Polytechnic Institute of Santarém and the research center CIPER of the Faculty of Human Kinetics from the University of Lisbon. This study received ethical approval by the Ethics Committee of the Faculty of Human Kinetics, from the University of Lisbon.

5.4.2. Setting

The intervention was implemented in six community centers, in five municipalities of West and Ribatejo regions of Portugal allowing the recruitment of participants living in small towns and rural areas. The exercise program “MAAP” (EG1) was implemented in three of these centers. The other groups attended the exercise program “NOPP” (EG2) in the other three settings. Eligible individuals were invited to attend a formal in-person screening and then to participate in one of the community centers without any payment.

5.4.3. Participants

Participants were considered eligible for the study if they were aged 65 years and older, community-dwelling living, understand the Portuguese language and agree to participate voluntarily in this study. The exclusion criteria were: to have a neurologic condition (e.g., dementia or Parkinson disease), a cardiovascular condition (e.g., stroke), or other abnormality that would influence the ability to answer a questionnaire, inadequate proficiency in the Portuguese language, to use a walking aid, presence of hip, knee or ankle prosthesis, foot disorders, or incapacity of performing exercises in the standing position. Older male and female adults were recruited through advertisements posted within the local community.

Participants were randomly assigned to each exercise intervention group (EG1 or EG2) taking into account the geographical proximity of their homes and intervention settings, i.e., they were given the opportunity to choose between, at least, two of the available settings. The participants of both groups were assessed at baseline and after 6 months of intervention. A maximal of 20 participants performing exercise at the same time were allowed due to practical, pedagogical, and methodologic issues related to the training.

Of a total of 40 participants recruited for the intervention 20 were engaged in the EG1, and 20 older adults were engaged in the EG2. Due to the fact that they missed (or “because they have missed”) the second assessment, five subjects were excluded from the analysis in EG1 (12.5% loss of follow-up) and 7 in EG2 (17.5% loss of follow-up).

Fifteen participants of the EG1 (mean age of 68.0 ± 5.9 years at baseline; 66.0 ± 16.4 kg of body mass; 85% females) and thirteen participants of the EG2 (mean age of 67.8 ± 5.2 years at baseline; 72.1 ± 10.3 kg of body mass; 85% females) were assessed. A description of the recruitment, randomization and assessment processes is depicted in Figure 7.

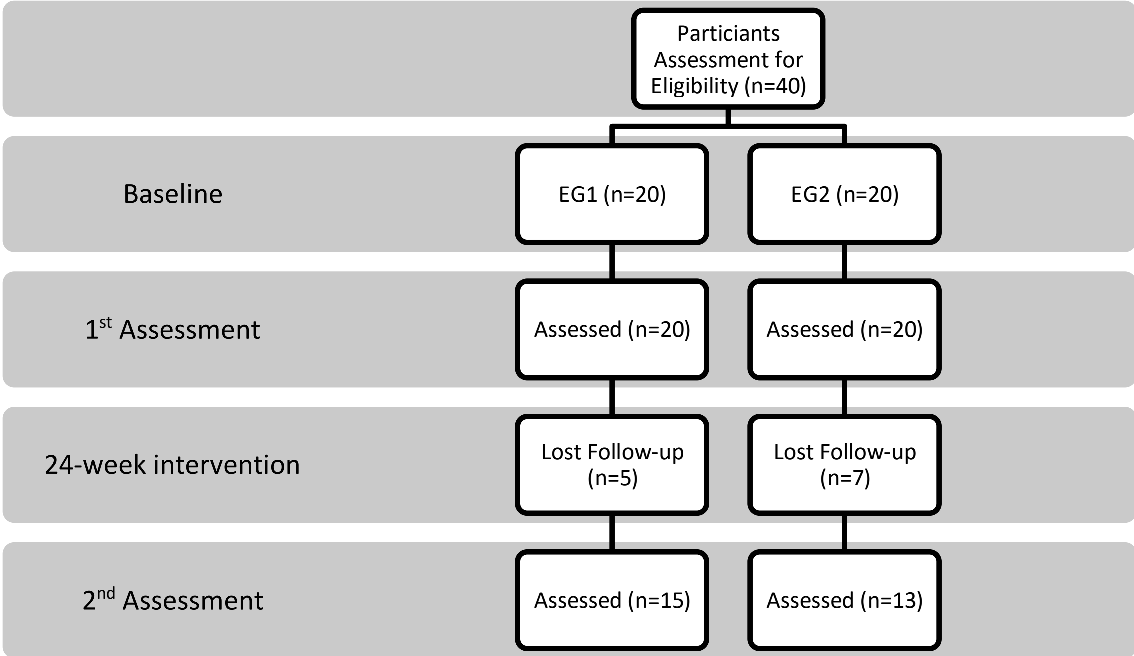

Figure 7. Flow diagram of the recruitment, randomization and assessment processes

The project manager explained the objectives of the study and answered all questions before asking the participant to consent the participation in the study. A written informed consent was obtained from all participants at the beginning of the intervention, before the allocation to the groups. All participants were instructed to maintain their normal lifestyle through the intervention.

5.4.4. Exercise Intervention

All exercise sessions included in both exercise programs were delivered by different graduated exercise specialists, blind to the intervention. Participants were instructed to wear comfortable sportswear and sports shoes during both interventions.

EG1 was engaged in an exercise program MAAP, which was controlled, periodized and organized, according to the structure presented in Ramalho et al. (2017). The rational is also explained in the study protocol (Ramalho et al. 2017). The MAAP was designed to focus specifically the postural stability, balance and strength in lower limbs, combined with aerobic exercise, at a level of intensity in accordance with the participants' functional capacities. The components of posture stability, balance and strength training were based on group exercise and circuit training. The aerobic component was based on walking and mobility group exercise.

During the first period of 12 weeks more emphasis was given to the development of postural control and balance, and the second period of 12 weeks, was more focused on strength and muscle resistance improvement in lower limbs. The exercise specialists responsible by NOPP (EG2) followed the same planning on all subgroup classes, in accordance with the recommendations provided by the American College of Sports Medicine (2014; 2017), Rose (2015), and King et al. (1998). The NOPP program was designed to focus balance, strength and aerobic exercise, without any specific periodization. A more detailed description of this exercise program is also described in Ramalho et al. (2017).

The participation of all subjects was controlled through attendance forms and session goals checklists. Participants with an attendance rate lower than 75% of the sessions in each of the programs' mesocycles would be excluded from the analysis. Nevertheless, all participants attended at least 95% of the sessions. The loss of follow-up refers to participants that missed one of the assessments, and for that reason were excluded from the analysis (Figure 7).

The independent variables of this study were the features (type, duration, frequency, intensity and progression/periodization) of the exercise programs.

5.4.5. Testing Procedures

All measurements were applied using standardized protocols and trained researchers.

Gait Assessment

Gait parameters were obtained using a Novel emed-x system platform (Münich, Germany) with a high sensor resolution mode with a sensor resolution of 4 sensors/cm^2 and a frame rate of 100 Hz. Gait parameters were recorded as participants walked barefoot across a 10 m walkway placed on the floor, at self-determined velocity. The participants performed few trials before data collection, in order to be familiarized with the task. Five stances from each foot from each participant were collected and analyzed. The portable equipment was used to collect data in the same setting where the exercise interventions and the other assessments took place.

The primary outcome variables were the following gait parameters: 1) Applied local force-maximum vertical ground reaction force (Max Force); 2) Maximum applied local pressure (Peak Pressure); 3) Maximum mean applied pressure (Max Mean Pressure); 4) Force-time integral in an anatomical area (FTI); 5) Pressure-time integral (PTI). For subsequent analysis of force and plantar pressure, each foot (right and left) was divided into six anatomical areas: "hindfoot", "midfoot", "medial forefoot", "hallux", "toes", and "lateral forefoot" (metatarsal heads), plus "total foot". The total foot and the six foot areas selected for analysis are depicted in Figure 8.

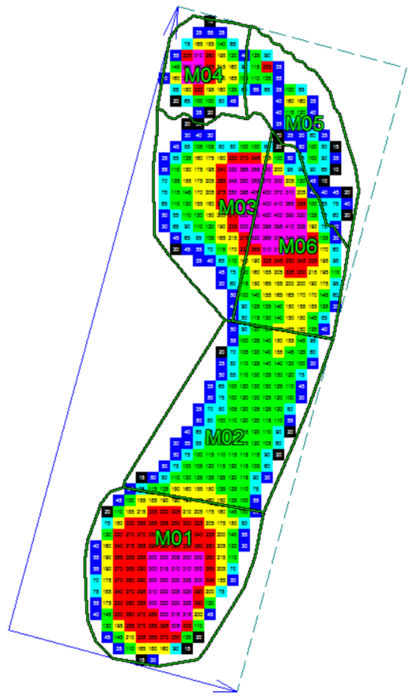

Figure 8. The six foot regions in analysis: M01 – Hindfoot (heel); M02 - Midfoot; M03 – Medial forefoot; M04 – Hallux; M05 – Toes; M06 – Lateral forefoot

The Novel software was used for data analysis. Force data were normalized to the body weight (BW). This process allows better comparisons between participants since it eliminates differences in body weight as a potential confounder during statistical analysis. Since a previous comparison showed no significant differences between right and left foot, the mean values of both feet were used in the subsequent statistical analysis.

Functional Fitness Assessment

Functional Fitness (FF) tests included in the "Senior Fitness Tests" (SFT) battery (Rikli and Jones 1999; 2013; Rose et al. 2006) were administered by trained examiners after engaging in a training workshop, which previously demonstrated a high inter-observer agreement for all FF tests (Moniz-Pereira et al. 2012). The tests "30sec chair stand", "8ft up&go" and "2-min walking" were used to assess lower limbs strength, agility and aerobic endurance, respectively. Both dynamic and static balance were evaluated through two tests each (FAB 1-4), included in the "Fullerton Advanced Balance Scale" (Rose et al. 2006). These FF parameters were the secondary variables of the study. All participants followed a familiarization session of 15 minutes (2 minutes for each test) one week before the baseline assessments.

Demographics, Health, and Physical Activity Assessment

The characteristics of the participants included in the study were: demographics, self-perception of health and falls prevalence, medication intake, physical activity levels, body mass, height, and body mass index (BMI).

Self-perception of health status and falls prevalence - defined as the experience of any falls during the period before assessments: previous 12 months at baseline and during the follow-up period - were assessed by a questionnaire designed and validated for the Portuguese Language and Culture (Valente 2012).

Physical activity (PA) profiles were also evaluated by a short version of "Yale Physical Activity Survey" (YPAS) (Dipietro et al. 1993), validated for the Portuguese population (Machado et al. 2016), which defines 6 distinct PA dimensions: 1) Vigorous activity; 2) Leisurely walking; 3) Moving; 4) Standing; and 5) Sitting; and a PA total score, considering a typical week. Both questionnaires were administered by face-to-face interviews involving the same trained examiners. The procedures are described elsewhere (Moniz-Pereira et al. 2012).

Height (m) and body mass (kg) were assessed using a stadiometer and calibrated scale SECA (model 220, Hamburg, Germany). BMI was calculated as body mass / $(height)^2$.

Statistical analysis

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS version 23.0) to obtain descriptive statistics (means and standard deviations) and to evaluate the effectiveness of the MAAP on the improvement of gait and functional fitness parameters in the EG1, when compared to the NOPP administered to the EG2. Data normality distribution was checked with the Shapiro-Wilk test. Paired t-tests (and the non-parametric Wilcoxon tests) were used to compare data at baseline and after 6 months of intervention. Independent samples t-tests (and the non-parametric Mann-Whitney tests) were performed to compare outcomes between groups (EG1 versus EG2). Statistical significance was set at p <0.05.

5.5. Results

The characteristics of the participants, as well as the functional fitness parameters (secondary variables) results in both groups, at baseline and after the exercise intervention, are described in Table 7.

Table 7. Characteristics of the participants and functional fitness results in both exercise groups, at baseline and after the 24-weeks exercise intervention

	Exercise Group 1 (EG1) N=15		Exercise Group 2 (EG2) N=13		
	Baseline	After Intervention	Baseline	After Intervention	
Factors	Mean±SD	Mean±SD	Mean±SD	Mean±SD	P<0.05
Body Weight (N)	653.01 ±81.23	647.78 ±80.04	676.3 ± 88.8	674.0 ± 82.8	
Body Mass Index (kg/m^2)	27.2 ± 3.5	26.4 ± 3.3	28.0 ± 2.5	27.6 ± 2.6	
Vigorous Walking (score units)	5.3 ± 12.0	9.7 ± 12.6	15.4 ± 16.2	9.6 ± 9.6	
Walking (score units)	**9.3 ± 5.2**	11.2 ± 7.7	**13.0 ± 12.8**	18.6 ± 13.7	¤
Moving (score units)	10.5 ± 3.2	11.2 ± 2.4	**12.8 ± 1.4**	**13.1 ± 1.5**	¥
Standing (score units)	7.9 ± 1.8	8.4 ± 1.9	9.0 ± 1.0	9.3 ± 1.0	
Sitting (score units)	2.3 ± 0.8	2.3 ± 0.8	2.3 ± 0.5	2.1 ± 0.5	
YPAS Total (score units)	51.3 ± 12.6	42.7 ± 16.5	52.4 ± 17.8	52.6 ± 15.4	
30sec Chair-Stand (number of repetitions)	15.3 ± 3.7	**16.4 ± 2.8**	16.3 ± 3.1	**21.2 ± 5.8**	¥, §
8 ft Up&Go (score units)	5.5 ± 1.2	5.0 ± 0.7	4.8 ± 0.8	5.1 ± 0.8	
2-minWalking (score units)	105.9 ± 21.4	111.7 ± 17.5	110.8 ± 21.5	111.8 ± 25.1	
FAB1 (score units)	4.00 ± 0.0	4.0 ± 0.0	4.0 ± 0.0	4.0 ± 0.0	
FAB2 (score units)	3.3 ± 1.0	3.7 ± 0.5	3.3 ± 1.0	3.6 ± 0.7	
FAB3 (score units)	3.2 ± 1.2	3.3 ± 1.2	3.3 ± 1.0	3.3 ± 0.8	
FAB4 (score units)	3.7 ± 1.0	3.7 ± 0.6	3.9 ± 0.3	3.9 ± 0.3	

SD = standard deviation; "30sec Chair-Stand" (CS) = lower limbs strength test; "8 foot up&go" (UP) = agility test; "2-min walking" = aerobic endurance test; FAB 1 and FAB2 = dynamic balance tests; FAB3 and FAB4 = static balance tests.

¥ Significant differences between IG1 and IG2 after intervention
¤ Significant differences between baseline and after intervention in IG1
§ Significant differences between baseline and after intervention in IG2

Regarding both exercise interventions, none of the participants reported any injury or complications in their feet during the intervention period and showed no signs of excessive fatigue or discomfort during assessments.

There were no differences between groups, at baseline and after the intervention, regarding self-perception of health (3.5 ± 0.4 score units), number of medications intake (2.5 ± 1.3), and falls prevalence in the last year (0.2 ± 0.1). There were no differences between groups regarding participants' body weight, BMI, and physical activity level, neither at baseline nor after the intervention. Exception for "moving score" which increased after the intervention.

Regarding the **functional fitness** variables there are no differences between groups at baseline. The results point to the maintenance of most functional fitness parameters after the 24-weeks exercise intervention. Exceptions for the "30sec Chair-Stand" test that increased in EG2 after intervention and in comparison, with EG1.

The gait parameters (primary outcomes) results in both groups, at baseline and after the exercise intervention are described in this chapter Appendix (Table 8 to Table 14).

At baseline, no significant differences between groups regarding the analyzed variables (Table 8).

The significant changes between baseline and after the intervention, in both groups are depicted in Figure 9 to Figure 13.

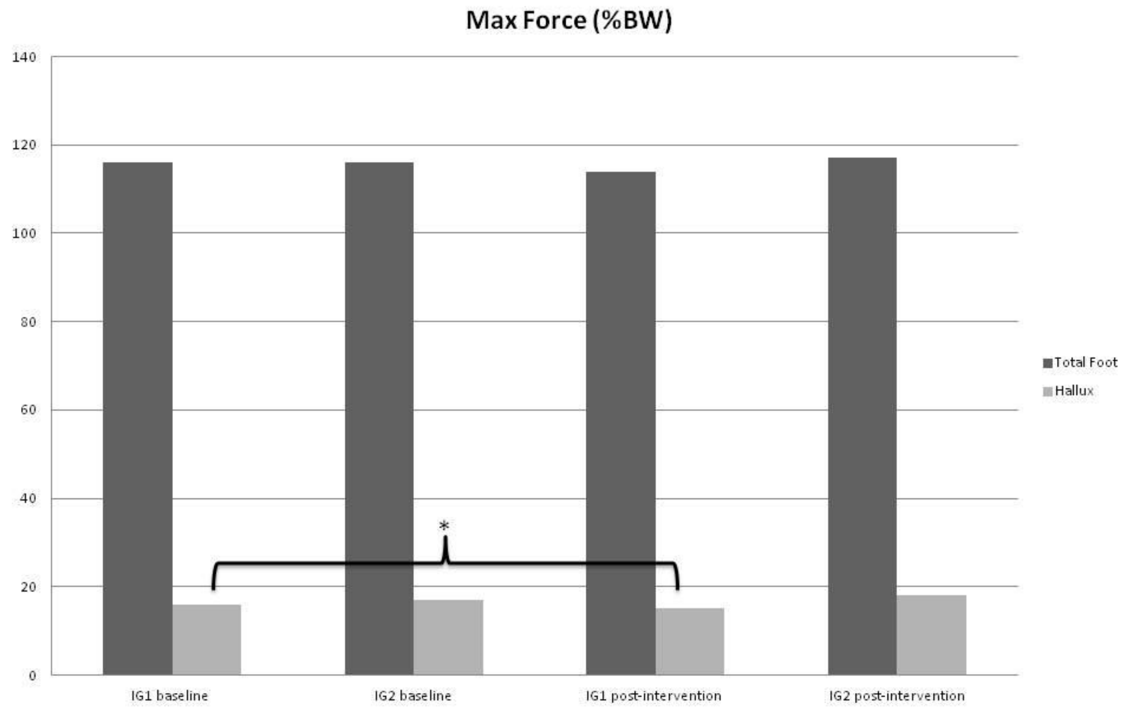

Figure 9. Significant changes between baseline and after intervention, in both groups, regarding maximal force (*p<0.05)

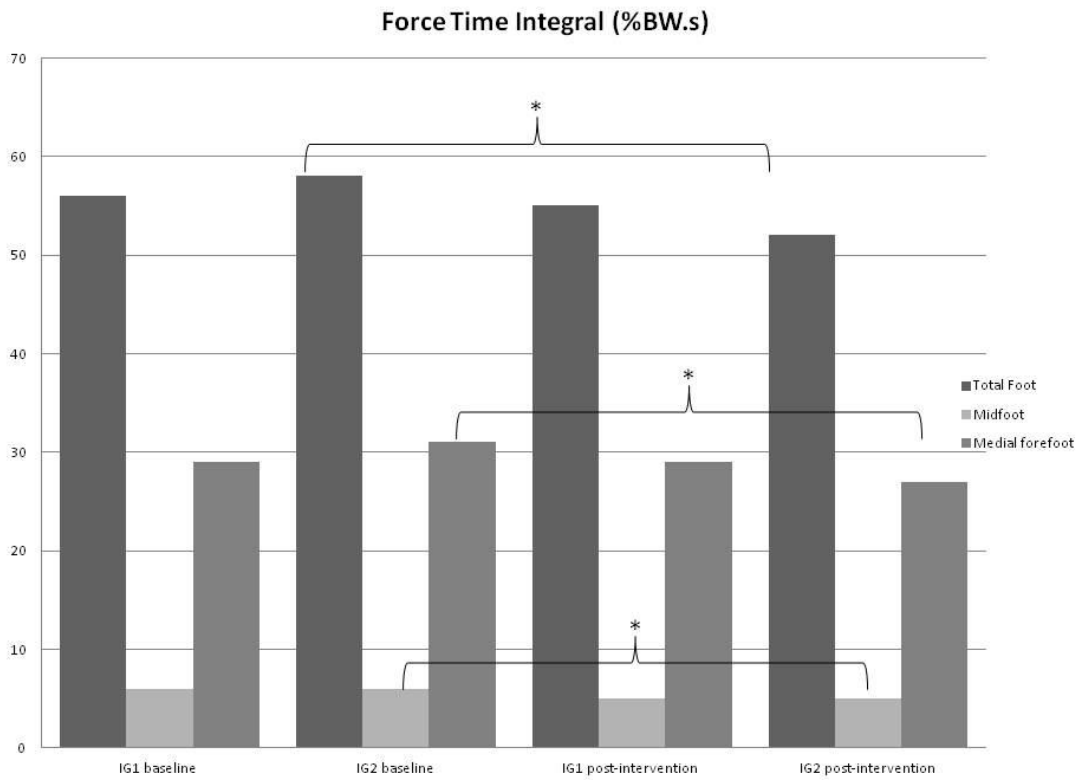

Figure 10. Significant changes between baseline and after intervention, in both groups, regarding force-time integral (*p<0.05)

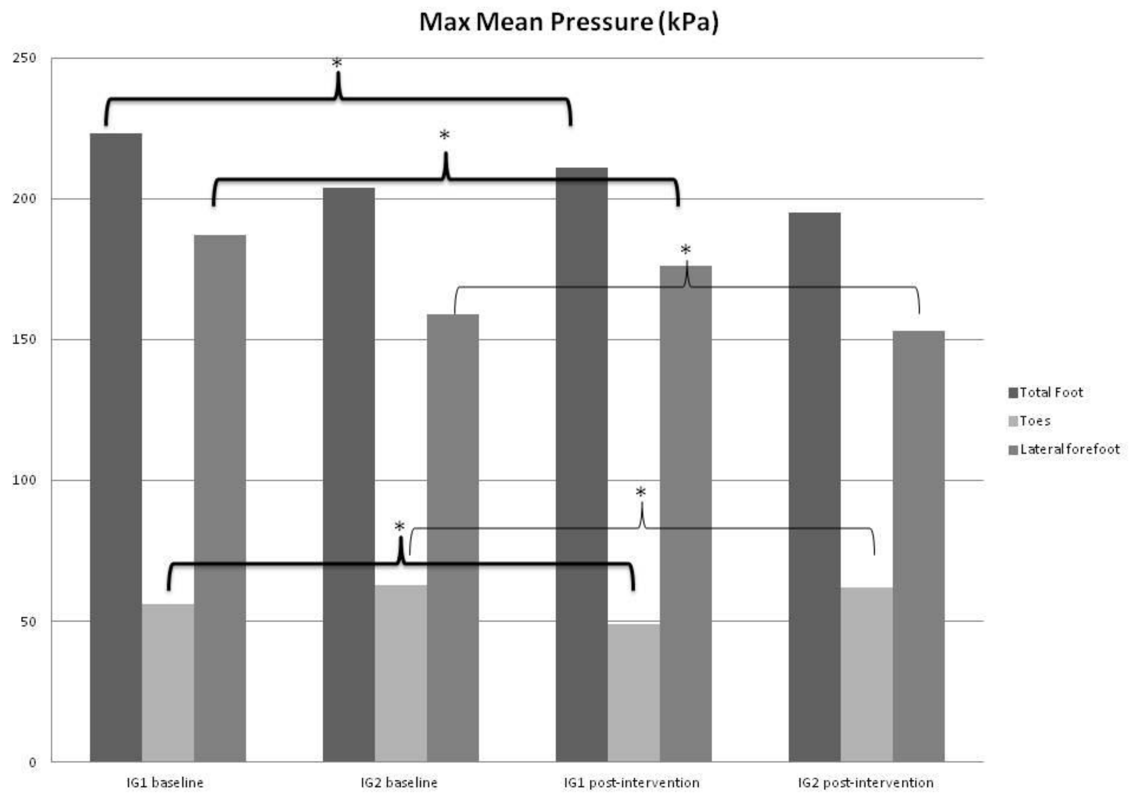

Figure 11. Significant changes between baseline and after intervention, in both groups, regarding maximal mean pressure (*p<0.05)

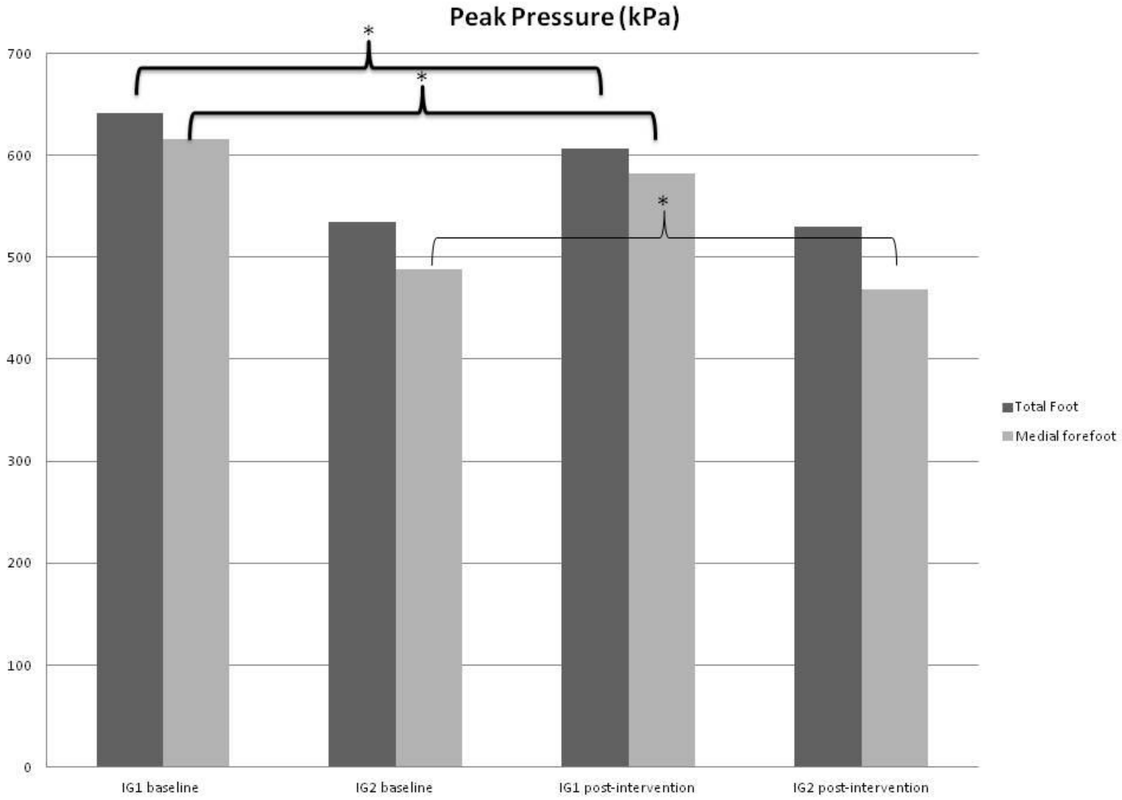

Figure 12. Significant changes between baseline and after intervention, in both groups, regarding peak pressure (*p<0.05)

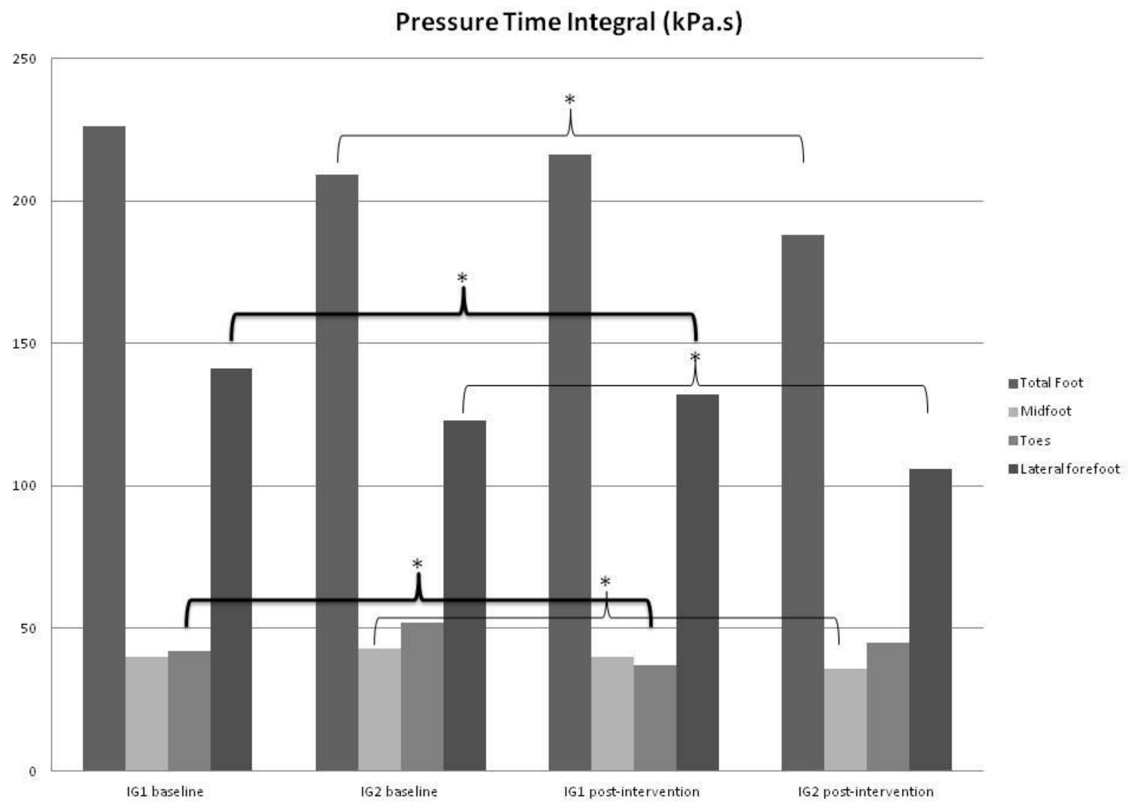

Figure 13. Significant changes between baseline and after intervention, in both groups, regarding pressure-time integral (*p<0.05)

Regarding the potential effects of the MAAP, the following parameters showed a significant decrease after the intervention: maximal force in the hallux; maximal mean pressure in all foot, toes, and lateral forefoot; peak pressure in all foot and medial forefoot; and PTI in toes and lateral forefoot. There was no change in the remaining assessed parameters.

For NOPP, it was observed a significant decrease after the intervention: force-time integral in all foot, midfoot, and medial forefoot; maximal mean pressure in toes, and lateral forefoot; peak pressure in the medial forefoot; and PTI in all foot, toes and lateral forefoot. There was no change in the remaining assessed parameters.

After the intervention, significant differences were observed between groups, in the following parameters: EG1 showed higher values than EG2 in FTI and PTI in the hindfoot region (Table 14).

5.6. Discussion

The aim of the study was to analyze the effects of a 6 months' community-based periodized exercise intervention on the improvement of gait parameters and functional fitness in an older adults' group when compared with a non-periodized program. We hypothesized that a periodized community program, in terms of its specific features (i.e., type, intensity, frequency, duration and progression), would be more effective in the improvement of gait and functional fitness parameters within the older population, than a non-periodized exercise program.

The EG2 program increased significantly the strength in lower limbs and showed higher plantar pressure values (FTI and PTI in the hindfoot region). The MAAP was designed to focus specifically the postural stability, balance and strength in lower limbs, combined with aerobic exercise, which could justify the improvement in gait stability. On the other hand, the increased effectiveness related to EG2 should be analyzed with cautious, because both groups were involved in exercise programs with the same type of exercises, differing only on the progression of the sessions and in the focus on postural control (EG1). The lack of improvement in most functional fitness parameters can be explained by the ceiling effect, mainly on the balance parameters. However, the motor skills developed in MAAP exercise intervention followed by EG2 led to an improved balance control, particularly by an increase in postural regulation as manifested in the observed decrease in plantar pressure. Moreover, with the reduction of plantar pressure manifested in hindfoot, it means that the initial contact of the gait was done with greater movement control, which represents an important indicator of the impact on adverse outcomes, namely on the decrease of the risk of falling. On the other hand, both elderly groups were quite fit at baseline, and exercise volume was not sufficient to promote a significant increase in overall functional fitness in EG1, but only to improve fewer functional capacities and to maintain other in this group. The motor skills developed in MAAP exercise intervention followed by EG2 led to an improved balance control, particularly by an increase in postural regulation as manifested in the observed decrease in plantar pressure. These results are quite similar to those obtained by Burton, Cavalheri, Adams et al. (2016). In this line, the American College of Sports Medicine (ACSM) issued what is considered as the gold standard of exercise prescription for healthy old adults (ACSM, 2014). However, a careful examination of this position stand suggests the number of included training variables (e.g., traditional variables such as training period, frequency, volume, intensity only) (Steib, Schoene, Pfeifer, 2010; Silva, Oliveira, Fleck, et al., 2013; Raymond, Bramley-Tzerefos, Jeffs, 2013) and by focusing only on direct comparisons of intervention groups (e.g., high- vs. low intensity), it seems weak to measure the effectiveness of exercise programs. Moreover, the absence of reference values about the minimum detectable difference in the various dimensions of functional fitness, does not allow us to consider considerations about the existence or not of improvements in the groups. In this study, this is especially important, because both intervention groups included active older adults, and the quantification of the dose–response relationships/answers are more difficult to achieve.

More research is needed with studies using larger sample sizes, and longer follow-up periods, to establish evidence-based recommendations.

However, our results are nonetheless important regarding the main outcomes, considering that higher plantar pressure values have been associated with a change in walking strategy and an increase in fall risk. Gait impairment has frequently been detected in frail patients, especially a reduction in gait speed (Schwenk et al. 2014; Ritt et al. 2017a). However, there are other gait parameters such as the ten spatiotemporal addressed by Ritt et al. (2017a) in a cross-sectional study. Moreover, those parameters might most accurately predict 1-year mortality (Ritt et al. 2017b).

We speculate that the long-term **effectiveness** of this type of exercise interventions will be established at the level of general mobility by means of adopting an active lifestyle, which can be translated into improved autonomy, independent living, and prevention of falls (Gillespie et al. 2012). The risk of falling associated with movement patterns in which elderly patients present higher GRF values in heel-contact (initial contact) may explain a higher plantar pressure in the hindfoot zone (which decreased in EG2). The results showed that exercise programs, both periodized and non-periodized issues and tailored to older adults, proved to be effective in reducing the age-related decline regarding functional fitness and improve gait parameters. In this line, the efficacy of the exercise programs on the reduction of risk of falling in the long term is promising (Rose and Hernandez, 2010; Gillespie et al. 2012; Van Abbema et al. 2015).

To our knowledge, this is the first study investigating the effect of exercise and its organization (periodized vs non-periodized program) on gait, based on peak forces and plantar pressures in independent community-dwelling older adults. Apart of this innovation, the major strength of this study was the ecological approach used, i.e., the development and implementation of exercise interventions, combining the advantages of a community group program with the efficacy of controlled exercise and a progressive stimulus tailored to participant's functional fitness level. The intervention was adapted to the typical community-based programs offered in rural areas and small towns to the older population. The programs were based on multiple component group exercise and showed great adherence, which in turn may contribute to compliance and long-term maintenance of older people.

Regarding the **implications for practice**, the present study has demonstrated that long-term periodized and non-periodized exercise programs tailored to older adults proved to be effective in reducing the age-related decline regarding functional fitness and selected gait parameters. Both exercise programs were safe, targeted to the physical fitness levels and can be used by exercise professionals in prescribing community exercise programs, as well as by health professionals in promoting active aging and health among older adults. It is important to highlight the relevance of postural control exercises in exercise programs for elderly people, due to the positive repercussions that may have on the gait pattern, regardless the improvement of functional fitness dimensions, leading to the prevention of falls in community-dwelling older adults.

Since an ecological approach was used, and as stated in the study protocol, the **limitations** of this study are related to the difficulties of randomization of the groups since older people were keener on participating in the program which provides a more convenient setting, either because it was not far from their homes or where were their friends. Moreover, the time-consuming events related to the assessment of different variables required extra time from the participants, and the loss of follow-up in this study was related to the second period of assessment. Future studies should have a larger sample size and a better randomized procedure to investigate the long-term effects of exercise training on gait loading parameters.

Further research should be focus on increasing the number of participants and age intervals, allowing the training effects of MAAP program, between active and sedentary older adults, with differentiated functional capacity. The equipment and methodology used for gait analysis has progressed substantially in recent years. Thus, longitudinal studies are required to test which gait parameters, either kinetics or kinematics are more sensitive to tailored exercise interventions.

5.7. Conclusion

Exercise programs tailored to older adults (periodized or non-periodized) are effective on mobility improvement and helps to maintain functional fitness in elderly. An explanation for these effects in our study could be higher quality in the execution of exercises due to supervision. In fact, evaluation of the exercise diaries revealed similar mean stages of progression between groups. This implies that a higher rate of exertion and consequently a larger adaptation was achieved in both experimental groups. The question remains as to why periodized program improved physical performance. It is possible that a higher dose needs to be applied in order to improve all functional parameters and thus a more effective improves in gait.

5.8. Chapter 5 Appendix

Table 8. Comparisons of gait parameters results between Intervention Group 1 and Intervention Group 2, at baseline

	Intervention Group 1 (N=15)	Intervention Group 2 (N=13)	
Gait parameters	**Mean ± SD**	**Mean ± SD**	**Sig. (2-tailed)**
All_FTI	56.0 ± 3.8	57.7 ± 9.2	0.905
All_PeakF	115.7 ± 5.8	116.4 ± 9.4	0.548
All_MeanP	222.7 ± 56.6	203.6 ± 36.1	0.456
All_PeakP	641.2 ± 194.1	534.8 ± 69.4	0.183
All_PTI	226.3 ± 58.1	208.5 ± 41.6	0.381
M01_FTI	16.5 ± 2.6	15.2 ± 2.6	0.215
M01_ PeakF	71.1 ± 9.1	67.5 ± 10.6	0.342
M01_MeanP	100.9 ± 28.5	86.8 ± 13.9	0.236
M01_PeakP	327.2 ± 111.6	293.1 ± 59.8	0.614
M01_PTI	74.8 ± 21.4	66.1 ± 10.6	0.456
M02_FTI	5.5 ± 3.4	5.7 ± 2.9	0.846
M02_ PeakF	19.9 ± 9.4	21.7 ± 9.0	0.624
M02_MeanP	47.2 ± 12.6	49.8 ± 14.3	0.627
M02_PeakP	135.1 ± 31.5	146.9 ± 27.8	0.319
M02_ PTI	39.5 ± 12.6	42.9 ± 16.1	0.537
M03_FTI	29.3 ± 4.1	31.0 ± 4.7	0.335
M03_ PeakF	95.8 ± 8.3	91.3 ± 5.4	0114
M03_MeanP	217.4 ± 60.1	186.5 ± 34.9	0,256
M03_PeakP	615.5 ± 211.4	487.6 ± 72.4	0.152

Table 9 (cont). Comparisons of gait parameters results between Intervention Group 1 and Intervention Group 2, at baseline

	Intervention Group 1 (N=15)	Intervention Group 2 (N=13)	
Gait parameters	Mean ± SD	Mean ± SD	Sig. (2-tailed)
M03_ PTI	169.4 ± 52.5	147.4 ± 30.6	0.427
M04_FTI	3.2 ± 1.357	3.9 ± 1.3	0.148
M04_ PeakF	16.4 ± 6.7	16.8 ± 4.8	0.844
M04_MeanP	91.3 ± 40.7	116.2 ± 39.8	0.123
M04_PeakP	348.1 ± 144.0	366.4 ± 89.8	0.706
M04_ PTI	69.7 ± 32.2	94.0 ± 51.2	0.139
M05_FTI	1.6 ± 0.6	2.0 ± 1.3	0.792
M05_ PeakF	7.7 ± 2.9	8.4 ± 4.1	0.599
M05_MeanP	56.4 ± 19.1	62.8 ± 35.0	0.648
M05_PeakP	182.8 ± 56.6	193.5 ± 97.2	0.724
M05_ PTI	42.4 ± 13.9	52.0 ± 36.9	0.581
M06_FTI	14.0 ± 3.1	15.3 ± 3.6	0.352
M06_ PeakF	44.6 ± 9.6	44.9 ± 7.0	0.932
M06_MeanP	187.1 ± 51.3	158.5 ± 24.4	0,300
M06_PeakP	493.1 ± 152.8	404.1 ± 43.6	0.126
M06_PTI	140.6 ± 43.6	122.5 ± 18.9	0.829

SD = standard deviation; PeakF = Applied local force-maximum vertical ground reaction force; PeakP = Maximum applied local pressure; MeanP = Maximum mean applied pressure; FTI = Force-time integral in an anatomical area; PTI = Pressure-time integral; M01 = Hindfoot; M02 = Midfoot; M03 = Medial forefoot; M04 = Hallux; M05 = Toes; M06 = Lateral forefoot. Significant differences in bold case.

Table 10. Comparisons of gait parameters results between baseline and after exercise intervention in Intervention Group 1

	Baseline (N=15)	Follow-up (N=15)	
Gait parameters	Mean ± SD	Mean ± SD	Sig. (2-tailed)
All_FTI	56.0 ± 3.8	55.2 ± 5.2	0.650
All_PeakF	115.7 ± 5.8	114.0 ± 6.0	0.394
All_MeanP	**222.7 ± 56.6**	**211.1 ± 47.0**	**0.041**
All_PeakP	**641.2 ± 194.1**	**606.5 ± 164.7**	**0.027**
All_PTI	226.3 ± 58.1	216.1 ± 46.7	0.256
M01_FTI	16.5 ± 2.6	16.5 ± 2.3	0.865
M01_ PeakF	71.1 ± 9.1	72.5 ± 9.6	0.532
M01_MeanP	100.9 ± 28.5	102.9 ± 26.2	0.439
M01_PeakP	327.2 ± 111.6	332.5 ± 86.7	0.363
M01_PTI	74.8 ± 21.4	75.6 ± 16.4	0.532
M02_FTI	5.4 ± 3.4	5.2 ± 3.5	0.349
M02_ PeakF	19.9 ± 9.4	18.9 ± 9.1	0.140
M02_MeanP	47.2 ± 12.6	47.6 ± 18.2	0.477
M02_PeakP	135.1 ± 31.5	139.7 ± 44.0	0.315
M02_PTI	39.5 ± 12.6	40.2 ± 17.6	0.609

Table 11 (cont). Comparisons of gait parameters results between baseline and after exercise intervention in Intervention Group 1

Gait parameters	Baseline (N=15) Mean ± SD	Follow-up (N=15) Mean ± SD	Sig. (2-tailed)
M03_FTI	29.3 ± 4.1	29.1 ± 4.9	0.776
M03_ PeakF	95.8 ± 8.3	94.8 ± 8.2	0.691
M03_MeanP	217.4 ± 60.1	206.9 ± 48.7	0.086
M03_PeakP	**615.5 ± 211.4**	**581.7 ± 177.5**	**0,019**
M03_PTI	169.4 ± 52.5	159.1 ± 46.9	0.075
M04_FTI	3.2 ± 1.4	2.9 ± 1.1	0.281
M04_PeakF	**16.4 ± 6.7**	**15.3 ± 6.7**	**0.017**
M04_MeanP	91.3 ± 40.7	86.8 ± 36.4	0.426
M04_PeakP	348.1 ± 144.0	329.3 ± 143.1	0.140
M04_PTI	69.7 ± 32.2	65.8 ± 28.7	0.406
M05_FTI	1.6 ± 0.6	1.4 ± 0.7	0.129
M05_ PeakF	7.7 ± 2.9	7.4 ± 3.8	0.820
M05_MeanP	**56.4 ± 19.1**	**49.1 ± 21.0**	**0.036**
M05_PeakP	182.8 ± 56.6	169.2 ± 66.2	0.201
M05_PTI	**42.4 ± 13.8**	**37.4 ± 14.4**	**0.047**
M06_FTI	14.0 ± 3.1	13.8 ± 3.2	0.532
M06_ PeakF	44.6 ± 9.6	43.9 ± 9.2	0.609
M06_MeanP	**187.1 ± 51.3**	**176.4 ± 41.5**	**0.027**
M06_PeakP	493.1 ± 152.8	469.0 ± 131.8	0.062
M06_PTI	**140.6 ± 43.6**	**132.0 ± 40.3**	**0.028**

SD = standard deviation; PeakF = Applied local force-maximum vertical ground reaction force; PeakP = Maximum applied local pressure; MeanP = Maximum mean applied pressure; FTI = Force-time integral in an anatomical area; PTI = Pressure-time integral; M01 = Hindfoot; M02 = Midfoot; M03 = Medial forefoot; M04 = Hallux; M05 = Toes; M06 = Lateral forefoot.
Significant differences in bold case.

Table 12. Comparisons of gait parameters results between baseline and after exercise intervention in Intervention Group 2

Gait parameters	Baseline (N=13) Mean ± SD	Follow-up (N=13) Mean ± SD	Sig. (2-tailed)
All_FTI	**57.7 ± 9.2**	**52.0 ± 5.7**	**0.015**
All_PeakF	116.4 ± 9.4	116.4 ± 9.9	0.937
All_MeanP	203.6 ± 36.1	195.0 ± 45.5	0.209
All_PeakP	534.8 ± 69.4	530.3 ± 110.8	0.814
All_PTI	**208.5 ± 41.6**	**187.9 ± 35.3**	**0.034**
M01_FTI	15.2 ± 2.6	14.6 ± 2.0	0.480
M01_ PeakF	67.5 ± 10.3	72.2 ± 7.7	0.209
M01_MeanP	86.8 ± 13.9	91.0 ± 13.7	0.439
M01_PeakP	293.1 ± 59.8	306.7 ± 48.3	0.583
M01_PTI	66.1 ± 10.6	63.8 ± 11.7	0.583
M02_FTI	**5.7 ± 2.9**	**4.7 ± 2.2**	**0.019**
M02_ PeakF	21.7 ± 9.0	20.6 ± 9.0	0.308

Table 13 (cont). Comparisons of gait parameters results between baseline and after exercise intervention in Intervention Group 2

Gait parameters	Baseline (N=13) Mean ± SD	Follow-up (N=13) Mean ± SD	Sig. (2-tailed)
M02_MeanP	49.8 ± 14.3	46.0 ± 12.9	0.136
M02_PeakP	146.9 ± 27.7	144.3 ± 31.2	0.784
M02_PTI	**42.9 ± 16.0**	**36.0 ± 10.6**	**0.019**
M03_FTI	**31.0 ± 4.7**	**27.4 ± 4.1**	**0.019**
M03_ PeakF	91.3 ± 5.4	90.0 ± 5.7	0.638
M03_MeanP	186.5 ± 34.9	179.3 ± 39.7	0.086
M03_PeakP	**487.6 ± 72.4**	**467.7 ± 102.6**	**0.019**
M03_PTI	147.4 ± 30.6	128.7 ± 34.4	0.075
M04_FTI	3.9 ± 1.3	3.6 ± 1.1	0.388
M04_ PeakF	16.8 ± 4.8	17.7 ± 5.5	0.388
M04_MeanP	116.2 ± 39.8	113.6 ± 42.7	0.695
M04_PeakP	366.4 ± 89.8	381.1 ± 108.2	0.530
M04_PTI	94.0 ± 51.2	80.3 ± 30.3	0.406
M05_FTI	2.0 ± 1.3	1.7 ± 1.0	0.129
M05_ PeakF	8.4 ± 4.1	8.4 ± 3.9	0.875
M05_MeanP	**62.8 ± 35.0**	**62.4 ± 29.6**	**0.036**
M05_PeakP	193.4 ± 97.2	208.8 ± 91.1	0.065
M05_PTI	52.0 ± 36.9	44.6 ± 20.5	0.209
M06_FTI	15.2 ± 3.6	12.9 ± 2.3	0.532
M06_ PeakF	44.9 ± 7.0	42.9 ± 5.6	0.583
M06_MeanP	**158.5 ± 24.4**	**153.2 ± 19.9**	**0.027**
M06_PeakP	404.1 ± 43.6	381.4 ± 57.3	0.062
M06_PTI	**122.5 ± 18.9**	**106.3 ± 17.6**	**0.028**

SD = standard deviation; PeakF = Applied local force-maximum vertical ground reaction force; PeakP = Maximum applied local pressure; MeanP = Maximum mean applied pressure; FTI = Force-time integral in an anatomical area; PTI = Pressure-time integral; M01 = Hindfoot; M02 = Midfoot; M03 = Medial forefoot; M04 = Hallux; M05 = Toes; M06 = Lateral forefoot.
Significant differences in bold case.

Table 14. Comparisons of gait parameters results between Intervention Group 1 and Intervention Group 2, after exercise intervention

Gait parameters	Intervention Group 1 (N=15) Mean ± SD	Intervention Group 2 (N=13) Mean ± SD	Sig. (2-tailed)
All_FTI	55.2 ± 5.2	52.0 ± 5.7	0.144
All_PeakF	114.0 ± 6.0	116.5 ± 9.9	0.432
All_MeanP	211.1 ± 47.0	195.0 ± 45.5	0.379
All_PeakP	606.5 ± 164.7	530.3 ± 110.8	0.182
All_PTI	216.1 ± 46.7	187.9 ± 35.3	0.096
M01_FTI	**16.5 ± 2.3**	**14.6 ± 2.0**	**0.030**
M01_ PeakF	72.5 ± 9.6	72.2 ± 7.7	0.936
M01_MeanP	102.9 ± 26.2	91.042 ± 13.671	0.272

Table 15 (cont). Comparisons of gait parameters results between Intervention Group 1 and Intervention Group 2, after exercise intervention

Gait parameters	Intervention Group 1 (N=15) Mean ± SD	Intervention Group 2 (N=13) Mean ± SD	Sig. (2-tailed)
M01_PeakP	332.5 ± 86.7	306.7 ± 48.3	0.365
M01_PTI	**75.626 ± 16.4**	**63.8 ± 11.7**	**0.046**
M02_FTI	5.2 ± 3.6	4.7 ± 2.2	0.654
M02_ PeakF	18.9 ± 9.1	20.7 ± 9.0	0.627
M02_MeanP	47.6 ± 18.2	46.0 ± 12.9	0.525
M02_PeakP	139.7 ± 44.0	144.3 ± 31.2	0.760
M02_ PTI	40.2 ± 17.6	36.0 ± 10.6	0.922
M03_FTI	29.1 ± 4.9	27.4 ± 4.1	0.361
M03_ PeakF	94.8 ± 8.2	90.0 ± 5.7	0.098
M03_MeanP	206.9 ± 48.7	179.3 ± 39.7	0.097
M03_PeakP	581.7 ± 177.6	467.7 ± 102.6	0.097
M03_ PTI	159.1 ± 46.9	128.7 ± 34.4	0.079
M04_FTI	2.9 ± 1.1	3.6 ± 1.1	0.145
M04_ PeakF	15.3 ± 6.7	17.7 ± 5.5	0.337
M04_MeanP	86.8 ± 36.4	113.7 ± 42.7	0.097
M04_PeakP	329.3 ± 143.1	381.1 ± 108.2	0.310
M04_ PTI	65.8 ± 28.7	80.3 ± 30.3	0.262
M05_FTI	1.5 ± 0.7	1.7 ± 1.0	0.407
M05_ PeakF	7.4 ± 3.8	8.4 ± 3.9	0.487
M05_MeanP	49.1 ± 21.0	62.4 ± 29.6	0.272
M05_PeakP	169.2 ± 66.3	208.7 ± 91.1	0.203
M05_ PTI	37.4 ± 14.4	44.6 ± 20.5	0.289
M06_FTI	13.8 ± 3.2	12.9 ± 2.3	0.444
M06_ PeakF	43.9 ± 9.2	43.0 ± 5.6	0.758
M06_MeanP	176.4 ± 41.5	153.2 ± 19.9	0.172
M06_PeakP	469.0 ± 131.8	381.4 ± 57.3	0,097
M06_PTI	132.0 ± 40.3	106.3 ± 17.6	0.118

SD = standard deviation; PeakF = Applied local force-maximum vertical ground reaction force; PeakP = Maximum applied local pressure; MeanP = Maximum mean applied pressure; FTI = Force-time integral in an anatomical area; PTI = Pressure-time integral; M01 = Hindfoot; M02 = Midfoot; M03 = Medial forefoot; M04 = Hallux; M05 = Toes; M06 = Lateral forefoot.
Significant differences in bold case.

5.9. References

American College of Sports Medicine (2014) ACSM's Resource Manual for Guidelines for Exercise Testing and Prescription, 7th ed. Lippincott Williams & Wilkins, Philadelphia

American College of Sports Medicine (2017). ACSM's Guidelines for Exercise Testing and Exercise Prescription, 10th ed. Philadelphia: Wolters Kluwer/ Lippincott, Williams and Wilkins. (ISBN-10: 1609136055; ISBN-13: 978-1609136055).

Amemiya A, Noguchi H, Oe M, Ohashi Y, Ueki K, Kadowaki T, Mori T, Sanada H (2014). Elevated plantar pressure in diabetic patients and its relationship with their gait features. Gait and Posture, 40(3), 408-414. PubMed doi: 10.1016/j.gaitpost.2014.05.063.

Bauman A, Merom D, Bull F, Buchner D, Singh MF (2016) Updating the Evidence for Physical Activity: Summative Reviews of the Epidemiological Evidence, Prevalence, and Interventions to Promote "Active Aging". The Gerontologist; 56 (S2) S268–S280. PubMed doi: 10.1093/geront/gnw031

Butterworth PA, Landorf KB, Gilleard W, Urquhart DM, Menz HB (2014). The association between body composition and foot structure and function: a systematic review. Obesity Reviews, 15(4), 348-357. PubMed doi: 10.1111/obr.12130.

Cadore EL, Rodríguez-Mañas L, Sinclair A, Izquierdo M (2013). Effects of different exercise interventions on risk of falls, gait ability, and balance in physically frail older adults: a systematic review. Rejuvenation Research, 16(2), 105-114. PubMed doi: 10.1089/rej.2012.1397.

Carter ND, Kannus P, Khan KM (2001). Exercise in the prevention of falls in older people: a systematic literature review examining the rationale and the evidence. Sports Medicine, 31(6), 427-438. PubMed doi: 0112-1642/01/0006-0427.

Chase JAD (2015). Interventions to increase physical activity among older adults: A meta-analysis. The Gerontologist, 55, 706–718. PubMed doi:10.1093/geront/gnu090

Chen MS, Lin TC, Jiang BC (2015). Aerobic and resistance exercise training program intervention for enhancing gait function in elderly and chronically ill Taiwanese patients. Public Health, 129(8), 1114-1124. PubMed doi: 10.1016/j.puhe.2015.04.018.

Chodzko-Zajko WJ, Proctor DN, Fiatarone Singh MA, Minson CT, Nigg CR, Salem GJ, Skinner JS (2009). American College of Sports Medicine position stand. Exercise and Physical Activity for Older Adults. Medicine & Science in Sports & Exercise, 41(7), 1510-1530. PubMed 1510.1249/MSS.1510b1013e3181a1510c1595c.

Chung MJ & Wang MJ (2012). Gender and walking speed effects on plantar pressure distribution for adults aged 20-60 years. Ergonomics, 55(2):194-200. PubMed doi: 10.1080/00140139.2011.583359.

Conn VS, Valentine JC, Cooper HM (2002). Interventions to increase physical activity among aging adults: A meta-analysis. Annals of Behavioral Medicine, 24(3), 190–200. PubMed doi:10.1207/S15324796ABM2403_04

Dipietro L, Caspersen CJ, Ostfeld AM, Nadel ER (1993). A survey for assessing physical activity among older adults. Medicine & Science in Sports & Exercise, 25(5), 628-642. PubMed

Fernando ME, Crowther RG, Lazzarini PA, Sangla KS, Wearing S, Buttner P, Golledge J (2016). Plantar pressures are higher in cases with active diabetic foot ulcers compared to controls despite a longer stance phase duration. BMC Endocr Disord, 16(1), 51 PubMed doi: 10.1186/s12902-016-013

Franco PS, Silva CB, Rocha ES, Carpes FP (2015). Variability and repeatability analysis of plantar pressure during gait in older people. Rev Bras Reumatol, 55(5), 427-33 PubMed doi: 10.1016/j.rbr.2015.03.006

Gillespie LD, Robertson MC, Gillespie WJ, Sherrington C, Gates S, Clemson LM, Lamb SE (2012). Interventions for preventing falls in older people living in the community. The Cochrane Database of Systematic Reviews, Sep 12;9:CD007146. PubMed doi: 10.1002/14651858.CD007146.pub3.

Hernandez D & Rose DJ (2008). Predicting which older adults will or will not fall using the Fullerton Advanced Balance scale. Archives Physical Medicine and Rehabilitation, 89(12), 2309-2315. PubMed doi: 10.1016/j.apmr.2008.05.020.

Iunes DH, Rocha CB, Borges NC, Marcon CO, Pereira VM, Carvalho LC (2014). Self-care associated with home exercises in patients with type 2 diabetes mellitus. PLoS One, 5, 9(12):e114151, eCollection 2014. PubMed doi: 10.1371/journal.pone.0114151.

Kenny R, Rubenstein LZ, Tinetti ME, et al. (2011). Summary of the updated American Geriatrics Society/British Geriatrics Society clinical practice guideline for prevention of falls in older persons. Journal of the American Geriatrics Society, 59(1), 148-157. PubMed doi: 10.1111/j.1532-5415.2010.03234.x.

King AC, Rejeski WJ, Buchner DM (1998). Physical activity interventions targeting older adults: A critical review and recommendations. American Journal of Preventive Medicine, 15(4), 316–333. PubMed doi: 10.1016/S0749-3797(98)00085-3

Keijsers NL, Stolwijk NM, Louwerens JW, Duysens J (2013). Classification of forefoot pain based on plantar pressure measurements. Clin Biomech (Bristol, Avon), 28(3):350-6. PubMed doi: 10.1016/j.clinbiomech.2013.01.012. Epub 2013 Feb 20.

Lalande X, Vie B, Weber JP, Jammes Y (2016). Normal values of pressures and foot areas measured in the static condition. J Am Podiatr Med Assoc, 106(4), 265-72 PubMed doi: 10.7547/14-008

Lee CE, Simmonds MJ, Etnyre BR, Morris GS (2007). Influence of pain distribution on gait characteristics in patients with low back pain: part 1: vertical ground reaction force. Spine (Phila Pa 1976), 20, 32(12):1329-1336. PubMed

Liu CJ & Latham NK (2011). Can progressive resistance strength training reduce physical disability in older adults? A meta-analysis study. Disability and Rehabilitation, 33(2):87-97. PubMed doi: 10.3109/09638288.2010.487145.

Liu CJ & Latham NK (2009). Progressive resistance strength training for improving physical function in older adults. Cochrane Database of Systematic Reviews, 3, CD002759. PubMed doi:10.1002/14651858.

Liu Y, Hu F, Li D, Wang F, Zhu L, Chen W, Ge J, An R, Zhao Y (2011). Does physical activity reduce the risk of prostate cancer? A systematic review and meta-analysis. European Urology, 60(5), 1029-1044. PubMed doi: 10.1016/j.eururo.2011.07.007.

Kim SG, Park JH (2015). The effects of dual-task gait training on foot pressure in elderly women. Journal of Physical Therapy and Science, 27: 143–4. PubMed doi

Machado M, Tavares C, Moniz-Pereira V, André HI, Ramalho F, Veloso AP (2016). Validation of YPAS-PT – The Yale Physical Activity Survey for Portuguese Older People. Science Journal of Public Health, 4(1), 72–80. http://doi.org/10.11648/j.sjph.20160401.20

Menz HB (2015). Biomechanics of the Aging Foot and Ankle: A Mini-Review. Gerontology;61:381–8. PubMed doi: 10.1159/000368357

Mickle KJ, Munro BJ, Lord SR, Menz HB, Steele JR (2010). Foot pain, plantar pressures, and falls in older people: a prospective study. Journal of the American Geriatrics Society, 58(10), 1936-1940. PubMed doi: 10.1111/j.1532-5415.2010.03061.x.

Moniz-Pereira V, Carnide F, Machado M, André HI, Veloso AP (2012). Falls in Portuguese older people: procedures and preliminary results of the study Biomechanics of Locomotion in the Elderly. Acta Reumatológica Portuguesa, 37, 324-332. PubMed

Monteiro MA, Gabriel RE, Neves E, Castro M, Sousa MF, Abrantes JM, Moreira MH (2010). Exercise effects in plantar pressure of postmenopausal women. Menopause, 17(5), 1017-1025. PubMed doi: 10.1097/gme.0b013e3181ddf6ef.

Nelson ME, Rejeski WJ, Blair SN, Duncan PW, Judge JO, King AC, Macera CA, Castaneda-Sceppa C (2007). Physical activity and public health in older adults: Recommendation from the American College of Sports Medicine and the American Heart Association. Medicine and Science in Sports and Exercise, 39(8), 1435–1445. PubMed doi:10.1249/mss.0b013e3180616aa2

O'Brien DL & Tyndyk M (2014). Effect of arch type and Body Mass Index on plantar pressure distribution during stance phase of gait. Acta of Bioengineering and Biomechanics, 16(2), 131-135. PubMed doi: 10.5277/abb140215

Parkatti T, Perttunen J, Wacker P (2012). Improvements in functional capacity from Nordic walking: a randomized-controlled trial among elderly people. Journal of Aging and Physical Activity, 20(1), 93-105 PubMed

Parmenter BJ, Raymond J, Dinnen P, Singh MA (2011). A systematic review of randomized controlled trials: Walking versus alternative exercise prescription as treatment for intermittent claudication. Atherosclerosis, 218(1), 1-12. PubMed doi: 10.1016/j.atherosclerosis.2011.04.024.

Paterson DH & Warburton DE (2010). Physical activity and functional limitations in older adults: a systematic review related to Canada's Physical Activity Guidelines. International Journal of Behavioral Nutrition and Physical Activity, 11(7):38. PubMed doi: 10.1186/1479-5868-7-38.

Ramalho F, Carnide F, Santos-Rocha R, André HI, Moniz-Pereira V, Machado M, Veloso AP (2017). Community-Based Exercise Intervention for Gait and Functional Fitness Improvement in an Older Population: Study Protocol. J Aging Phys Act. 2017 Jan;25(1):84-93. Epub 2016 Sep 6 PubMed doi: 10.1123/japa.2015-0290.

Razak AHA, Zayegh A, Begg RK, Wahab Y (2012). Foot Plantar Pressure Measurement System: A Review. Sensors (Basel), 12, 9884-9912. PubMed doi:10.3390/s120709884.

Rikli RE & Jones CJ (1999). Development and validation of a functional fitness test for community-residing older adults. Journal of Aging and Physical Activity, 7(2), 129-161.

Rikli RE & Jones CJ (2013). Senior Fitness Test Manual (2nd ed.). Champaign, IL: Human Kinetics. (ISBN-13: 9781450411189)

Ritt M, Schülein S, Lubrich H, Bollheimer LC, Sieber CC, Gassmann K-G. High-technology based gait assessment in frail people: associations between spatio-temporal and three-dimensional gait characteristics with frailty status across four different frailty measures. J Nutr Health Aging 2017; 21(3): 346-53. doi: 10.1007/s12603-016-0764-4

Ritt M, Ritt JI, Sieber CC, Gaßmann KG. Comparing the predictive accuracy of frailty, comorbidity, and disability for mortality: a 1-year follow-up in patients hospitalized in geriatric wards. Clin Interv Aging. 2017 Feb 8;12:293-304. doi: 10.2147/CIA.S124342. eCollection 2017.

Robinson CC, Balbinot LF, Silva MF, Achaval M, Zaro MA (2013). Plantar pressure distribution patterns of individuals with prediabetes in comparison with healthy individuals and individuals with diabetes. Journal of Diabetes Sciences and Technology, 7(5), 1113-1121. PubMed

Rose D, & Hernandez D (2010). The role of exercise in fall prevention for older adults. Clinical Geriatrics Medicine, 26, 607-631. PubMed doi: 10.1016/j.cger.2010.07.003.

Rose DJ (2015). Fallproof!: a comprehensive balance and mobility training program (2nd ed.). Champaign, IL: Human Kinetics. (ISBN-13: 9781492527848)

Rose DJ, Lucchese N, Wiersma LD (2006). Development of a multidimensional balance scale for use with functionally independent older adults. Archives of Physical Medicine and Rehabilitation, 87(11), 1478-1485. PubMed doi: 10.1016/j.apmr.2006.07.263.

Rubenstein LZ, Josephson KR, Trueblood PR, Loy S, Harker JO, Pietruszka FM, Robbins AS (2000). Effects of a group exercise program on strength, mobility, and falls among fall-prone elderly men. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 55(6), M317-M321. PubMed doi: 10.1093/gerona/55.6.M317

Schwenk M, Howe C, Saleh A, Mohler J, Grewal G, Armstrong D, Najafi B (2014). Frailty and technology: a systematic review of gait analysis in those with frailty. Gerontology, 60(1), 79-89. PubMed doi: 10.1159/000354211.

Seco J, Abecia JC, Echevarría E, Barbero I, Torres-Unda J, Rodriguez V, Calvo JI (2012). A long-term physical activity training program increases strength and flexibility, and improves balance in older adults. Journal of Aging and Physical Activity, 38, 37-47. PubMed doi: 10.1002/rnj.64.

Shekelle PG, Maglione MA, Chang JT, et al. (2003). Falls prevention interventions in the Medicare population. Santa Monica, CA: RAND Corporation. http://www.rand.org/pubs/reprints/RP1230.

Sherrington C, Tiedemann A, Fairhall N, Close JC, Lord SR (2011). Exercise to prevent falls in older adults: an updated meta-analysis and best practice recommendations. New South Wales Public Health Bulletin, 22(4), 78-83. PubMed doi: 10.1071/NB10056.

Staheli LT, Chew DE, Corbett M (1987). The longitudinal arch. A survey of eight hundred and eighty-two feet in normal children and adults. Journal of Bone and Joint Surgery America, 69A:426–8.

Strohacker K, Fazzino D, Breslin WL, Xu X (2015). The use of periodization in exercise prescriptions for inactive adults: A systematic review. Preventive Medicine Reports, 2, 385–396. PubMed doi: 10.1016/j.pmedr.2015.04.023

Sullivan J, Burns J, Adams R, Pappas E, Crosbie J (2015). Plantar heel pain and foot loading during normal walking. Gait & Posture, 41(2), 688-693. PubMed doi: 10.1016/j.gaitpost.2015.01.025.

Tak E, Kuiper R, Chorus A, Hopman-Rock M (2013). Prevention of onset and progression of basic ADL disability by physical activity in community dwelling older adults: a meta-analysis. Aging Research Reviews, 12(1):329-38. PubMed doi: 10.1016/j.arr.2012.10.001.

Valente S (2012). Validação de um questionário de saúde e identificação de factores de risco de quedas para a população idosa portuguesa [Validation of a health questionnaire and identification of fall risk factors among the Portuguese older population] (Master Thesis). Faculdade de Motricidade Humana - Universidade Técnica de Lisboa, Cruz-Quebrada.

Van Abbema R, De Greef M, Crajé C, Krijnen W, Hobbelen H, Van Der Schans C (2015). What type, or combination of exercise can improve preferred gait speed in older adults? A meta-analysis. BMC Geriatrics, 15(1), 72. PubMed doi: 10.1186/s12877-015-0061-9.

van der Bij AK, Laurant MG, Wensing M (2002). Effectiveness of physical activity interventions for older adults: a review. American Journal of Preventive Medicine, 22(2):120-33. PubMed doi: 10.1016/S0749-3797(01)00413-5

Wang RY, Wang YL, Cheng FY, Chao YH, Chen CL, Yang YR (2015). Effects of combined exercise on gait variability in community-dwelling older adults. Age (Dordr), Jun;37(3):9780. PubMed doi: 10.1007/s11357-015-9780-2. Epub 2015 Apr 25.

Weist R, Eils E, Rosenbaum D (2004). The influence of muscle fatigue on electromyogram and platar pressure patterns as an explanation for the incidence of metatarsal stress fractures. American Journal of Sports Medicine, 32, 1893-8. PubMed

Wonneberger M & Schmidt S (2015). Changes of gait parameters following long-term aerobic endurance exercise in mildly disabled MS patients: an exploratory study. European Journal of Physical Rehabilitation and Medicine, 51(6):755-62. PubMed

[no authors listed] (2001). Guideline for the prevention of falls in older persons. American Geriatrics Society, British Geriatrics Society, and American Academy of Orthopaedic Surgeons Panel on Falls Prevention. Journal of the American Geriatrics Society, 49(5), 664-672. PubMed doi: 10.1046/j.1532-5415.2001.49115.x

6. General Discussion and Future Directions

6.1. Discussion

The main purpose of this thesis was to design and evaluate the effectiveness of a long-term exercise program, focused on postural stability and improving the mechanical efficiency of walking, which, in turn, is expected to contribute to improved functional capacity and promote autonomy of the older population. To reach this purpose 3 main studies were conducted:

1 – A narrative review of the available evidence on the following topics: (1) how important is gait ability in relation to the active aging process?; (2) which gait parameters can be used as an expression of the functionality of older adults?, and (3) whether physical activity interventions have a positive effect on gait parameters;

2 – Development of a study protocol regarding a community-based exercise intervention (More Active Aging Program-MAAP) for gait and functional improvement in the older adult population;

3 – Development of a quasi-experimental study to analyze the effects of a MAAP intervention on improvement of gait parameters and functional fitness in the older adult population.

An epidemiological approach was followed, by an experimental design, including specific biomechanical methodologies to assess the gait pattern, occurrence of falls, health status, and functional fitness in the Portuguese elderly population. We also highlight the relevant social role of the MAAP intervention in a community setting.

In the present discussion section, the main findings are summarized and discussed, in addition to the deeper discussion presented in chapters 3 to 5.

There is strong evidence that appropriately designed intervention programs can prevent adverse outcomes in older adults, namely, frequency and risk of falling, disability, gait impairments and loss of autonomy (Dipietro et al., 2019; Gillespie et al., 2012; Sherrington, Tiedemann, Fairhall, Close, & Lord, 2011). Nonetheless, according to the Eurostat, only 19.2% of older adults fulfill the minimum criteria for guidelines of physical activity (Strandell & Wolff, 2019).

A Cochrane systematic review (Sherrington et al., 2019) established that exercise interventions reduce the rate of falls by 34% (number of falls per person) and risk of falling by about 29%

(proportion of people having one or more falls) in community-dwelling older people. Furthermore, exercise as a single intervention has a fall prevention effect, similar to multifaceted interventions, suggesting implementation of exercise as a stand-alone intervention may be the optimal and potentially most cost-effective approach to fall prevention at a population level (Dipietro et al., 2019). However, systematic reviews have shown through randomized clinical trials (RCT) of the effectiveness of exercise programs on several outcomes' prevention have heterogeneous in risk of bias, outcomes assessment methods, populations involved and content of exercise programs (Dipietro et al., 2019).

Considering the above limitations, we developed a narrative review to summarize the state of the art on the effect of exercise on gait, functional capacity, and its impact on fall prevention in older adults (chapter 3). This systematization allows us to show that gait analysis is a well-established tool for the quantitative assessment of gait disturbances, supporting functional assessment and helping to predict adverse mobility outcomes (Baker, Esquenazi, Benedetti, & Desloovere, 2016; Pothier et al., 2018). This is also relevant for detecting gait deficits that cannot yet be seen by performance tests, with well-established reliability properties (Pothier et al., 2018). Consideration of mobility, functional status, fall risk and cognition should be an integral part of every comprehensive geriatric assessment. Quantitative gait analysis allows not only the early detection of gait deficits and fall risk, but also of cognitive deficits (Lacroix, Hortobagyi, Beurskens, & Granacher, 2017). Early detection allows for timely implementation of targeted interventions to improve gait and/or cognition.

Regarding exercise program guidelines, the results of this narrative review suggest that aerobic/resistance exercise can clinically improve spontaneous walking speed, a functional vital sign, in older adults. Additionally, supervised balance and/or resistance training programs were more effective than unsupervised programs in older adults (Pothier et al., 2018). Therefore, it is recommended that supervised sessions (i.e., 2 out of 3 sessions/week) are included in balance/resistance training programs to effectively improve balance and muscle strength/power in older adults.

Finally, it is important to highlight that findings from RCTs regarding the effects of exercise on other gait parameters are inconsistent and scarce, namely for the kinetic variables, representative of biomechanical loading (Sanchis-Sanchis, Blasco-Lafarga, Encarnacion-Martinez, & Perez-Soriano, 2020).

Considering the existing evidence and the limitations stated above, a community-based exercise Intervention (MAAP) was designed to improve gait and functional fitness in older adults – the More Active Aging Program (MAAP). Prior to its implementation, a respective protocol was established with the aim of describing the rationale, design and methods that will be subsequently implemented in the community context (Chapter 4). Briefly, MAAP is a well-periodized community program, in terms of type of exercise and intensity progression to monitor and achieve better results on gait and functional fitness domains in the elderly parget population. We hypothesized a 36-week intervention, considering the evidence that short duration interventions (up to 12 weeks) presented low impact in the maintenance of functional capacities and mobility (Gillespie et al., 2012). Primary outcome variables were the gait parameters operationalized plantar pressure variables: (1) Applied local force-maximum vertical ground reaction force (Max Force); 2) Maximum applied local pressure (Peak Pressure); 3) Maximum mean applied pressure (Max Mean Pressure); 4) Force-time integral in an anatomical area (FTI); 5) Pressure-time integral (PTI). The secondary outcome variables were aerobic endurance, lower limb strength, agility, and static and dynamic balance (Rikli & Jones, 1999; Rikli & Jones, 2013). All parameters were assessed and monitored every 12 weeks (i.e., 4 assessment periods), by trained examiners (Moniz-Pereira, Carnide, Machado, Andre, & Veloso, 2012).

Our study used a multicenter approach and included two groups of older adults: an intervention group (G1) that received a three-phased intervention (50 min per session) with follow-up. The phase I (first cycle of 12 weeks) was characterized by the development of postural control and balance; phase II (13 to 24 weeks) was focused on strength and muscle resistance improvement in lower limbs; and phase III (25 to 36 weeks) was centered on the development of the fitness components in a more autonomous way. The control group received a non-periodized intervention with follow-up within the same period of time. This option was based on the fact that exercise interventions have been found to be effective when delivered in a group setting (Sherrington et al., 2019). Additionally, the optimal features of successful fall prevention exercise programs are not yet clear, but programs that are multicomponent (e.g., target both strength and balance) (Gillespie et al., 2012), and programs that include balance training, appear to be particularly effective (Sherrington et al., 2019).

The MAAP program was designed to focus specifically on postural stability, balance and strength in lower limbs, combined with aerobic exercise, at a level of intensity consistent with the participants' functional capacities, and the existing evidence on the role of each component in preserving functional fitness and preventing falls (Carter, Kannus, & Khan, 2001; McInnes, Gibbons, & Chandler-Oatts, 2005; Panel on Prevention of Falls in Older Persons & British Geriatrics, 2011; Shekelle et al., 2003; Sherrington et al., 2011).

The effectiveness of the MAAP intervention was operationalized by a quasi-experimental study (Chapter 5). This study design is justified by the well-known difficulties of assigning individuals to experimental and control groups since older people will be keener on participating in the program in a more convenient setting (i.e., not far from home).

The intervention was implemented in six community centers, in five municipalities of the West and Ribatejo regions of Portugal allowing the recruitment of participants living in small towns and rural areas. The exercise program “MAAP” (EG1) was implemented in three of these centers. The other group attended the exercise program “NOPP” (EG2) in the other three settings. All exercise sessions included in both exercise programs were delivered by different, graduate exercise specialists, blind to the intervention.

Participants were randomly assigned to each exercise intervention group (EG1 or EG2) taking into account the geographical proximity of their homes and intervention settings, i.e., they were given the opportunity to choose between, at least, two of the available settings. The participants of both groups were assessed at baseline and after 24 weeks of intervention. A maximum of 20 participants performing exercise at the same time was allowed due to practical, pedagogical, and methodologic issues related to the training.

The obtained results show that participants of the NOPP program (EG2) significantly increased the strength in lower limbs and showed higher plantar pressure values (FTI and PTI in the hindfoot region). These results may be explained by the fact that MAAP program was designed to focus specifically on postural stability, balance, and strength in lower limbs, combined with aerobic exercise, which could justify the improvement in gait stability. On the other hand, the increased effectiveness related to the NOPP program should be analyzed with cautious, because both groups were involved in exercise programs with the same type of exercises, differing only in the progression of the sessions and in the focus on postural control (EG1). Another justification could be attributed to the exercise volume being insufficient to promote a significant increase in overall functional fitness in EG1, but only to improve fewer functional capacities and to maintain others in this group. This interpretation is further supported by the ceiling effect observed in follow-up assessments, mainly on the balance parameters.

Nevertheless, the motor skills developed in the MAAP exercise intervention followed by EG2 led to improved balance control, particularly through an increase in postural regulation demonstrated by a decrease in plantar pressure. Moreover, with the reduction of plantar pressure manifested in the hindfoot, it means that the initial contact of the gait was made with greater movement control, which represents a relevant indicator of the impact on adverse outcomes, namely decreased risk of falling (Burton et al., 2015).

However, a careful examination suggests the number of included training variables (e.g., traditional variables such as training period, frequency, volume, intensity only) is not sufficient to evaluate the effectiveness of intervention programs (Raymond, Bramley-Tzerefos, Jeffs, Winter, & Holland, 2013; Silva, Oliveira, Fleck, Leon, & Farinatti, 2014; Steib, Schoene, & Pfeifer, 2010). Additionally, focusing the results analysis only on direct comparisons of intervention groups (e.g., high- vs. low intensity), appears a poor way tto measure the effectiveness of these intervention programs (Sherrington et al., 2019).

The long-term effectiveness of the MAAP will be established at the level of general mobility by means of adopting an active lifestyle, which can be translated into improved autonomy and independent living, and prevention of falls (Gillespie et al., 2012). The risk of falling associated with movement patterns in which older adults present higher GRF values in heel-contact (initial contact) may explain a higher plantar pressure in the hindfoot zone (which decreased in EG2). Our results showed that exercise programs, both periodized and non-periodized issues and tailored to older adults, proved to be effective in reducing the age-related decline regarding functional fitness and improve gait parameters. In this line, the efficacy of the exercise programs on the reduction of risk of falling in the long term is promising (Gillespie et al., 2012; Rose, 2010; Van Abbema et al., 2015).

To our knowledge, this was the first study investigating the effect of exercise and its organization (periodized vs non-periodized program) on gait, based on peak forces and plantar pressures in independent community-dwelling older adults. In addition to this innovation, the major strength of this study was the ecological approach used, i.e., the development and implementation of exercise interventions, combining the advantages of a community group program with the efficacy of controlled exercise and a progressive stimulus tailored to each participant's functional fitness level. The intervention was adapted to the typical community-based programs offered to the older population in rural areas and small towns. The programs were based on multiple component group exercise and showed great adherence, which in turn may contribute to compliance and long-term maintenance of older people. The experimental study was preceded by a study protocol, supporting the scalability of the MAAP to other national and international settings.

Clearly, our study has some limitations. First, the difficulties of randomization of the participants assigned to both groups, since they were available to participate in the program in a more convenient setting. And second, the similarities between groups' participants' attributes and the reduced sample size. Both were limitations to testing more fully our hypotheses.

In addition, the fitness instructors of the control group were not blind to the objectives of the intervention. So they may give some emphasis on balance training and, therefore, promote the development of this physical capacity as in the intervention group. The time-consuming events related to the assessment of different variables required extra time and planning, in addition to other activities related to the exercise program, requiring the attendance of the participants.

However, our results are nonetheless important regarding the main outcomes, considering that higher plantar pressure values have been associated with a change in walking strategy and an increase in fall risk and are aligned with those obtained by Sanchis-Sanchis et al. (2020). Gait impairment has also been detected in frail patients, especially a reduction in gait speed (Schwenk (Ritt, Ritt, Sieber, & Gassmann, 2017; Schwenk et al., 2014). However, there are other gait parameters such as spatiotemporal ones (Ritt, Ritt, et al., 2017). Moreover, those parameters might most accurately predict health-adverse outcomes (Ritt, Jager, Ritt, Sieber, & Gassmann, 2017).

More research is needed with studies using larger sample sizes, and longer follow-up periods, to establish evidence-based recommendations.

6.2. Implications for practice

Well-designed exercise programs reduce the rate of falls and the number of people experiencing falls amongst older people living in the community (high-certainty evidence) (Sherrington et al., 2019). However, the effects of exercise programs are uncertain for other non-fall outcomes, such as gait parameters and physical capacities, which in turn may have a positive impact on physical performance and independency, or at least are less reported in the RCTs that form part of our review.

The exercise programs included in our studies have demonstrated that long-term periodized and non-periodized exercise programs, tailored to older adults proved to be effective in reducing the age-related decline, mainly in what respect to physical capacities and selected gait parameters.

Both exercise programs aim to improve the physical fitness levels of older participants and can be used as community exercise programs in a safe way. Additionally, it is recommended that health professionals are informed in order to counsel their users on the promotion of healthy aging within the community. It is important to highlight the relevance of postural control exercises in exercise programs for elderly people, due to the positive effects on the gait pattern, regardless of the improvement in functional fitness dimensions, leading to the prevention of falls in community-dwelling older adults.

Furthermore, Health and Fitness companies should reinforce promotional strategies in aging communities to encourage regular exercise among the community-dwelling older adults. However, much controversy remains regarding the effects of exercise and physical activity on the gait pattern of older adults.

Exercise programs were effective when they were delivered in small-group compositions, by professionals trained and certified in exercise and health. There is likely to be a greater absolute impact in people identified as presenting higher risk of falling, but there is benefit also for those who are at more general risk in the community. Although trial follow-up was in 24 weeks in the main comparison, there may also be longer-term benefits of introducing fall prevention exercise habits in people in the general community.

The results of our investigation were translated into outputs suitable for health exercise professionals, constituting training instruments for the implementation of exercise programs that are safe and adapted to the physical capacities of the elderly population (with associated risk of falling).

We also believe that the knowledge produced can be a starting point for rethinking certified training for exercise and health professionals, as a means of deepening understanding of the impact of supervised physical exercise on improved physical capacities and gait patterns in the elderly population.

6.3. Implications for research

Further work is needed to understand the relative impact of different exercise programs on gait and specific physical capacity.

Since an ecological approach was used, and as stated in the study protocol, the limitations of this study are related to the difficulties of randomization of the groups. Future studies should have a larger sample size and a better randomized procedure to investigate the long-term effects of exercise training on functional capacity and gait loading parameters.

Additionally, further research should be directed towards a wider range of age intervals, contributing to the investigation of differential effects of exercise in people of different ages and baseline physical capacity, as these are individual-level rather than trial-level characteristics. Moreover, we expect to evaluate the training effects of the MAAP, between active and sedentary older adults. Finally, the equipment and methodology used for gait analysis has progressed substantially in recent years. Thus, longitudinal studies are required to test which gait parameters, either kinetics or kinematics, are more sensitive to tailored exercise interventions. It is important that studies are performed using standardized protocols that would allow later comparisons of the results obtained by different research teams. The undertaking of such studies, especially RCTs, might afford more reliable answers. Additionally, it will be important to consider a standardized analytical approach to gait analysis that will provide clinicians and researchers with objective evidence of foot function and adaptations in older people with or without specific clinical conditions.

Such studies will need to be very large to adequately distinguish effects between interventions. Large studies are also needed to establish the effect of fall prevention interventions on falls warranting clinical concern, as such falls are particularly costly to health systems and impactful for individuals. Individual participant data meta-analysis could contribute further to the investigation of differential effects of exercise in people of different ages and baseline fall risks, as these are individual-level rather than trial-level characteristics. There is an urgent need to investigate strategies to enhance implementation of effective exercise-based fall prevention interventions into routine care of older people by healthcare professionals and community organizations in a preventive approach.

6.4. References

Baker, R., Esquenazi, A., Benedetti, M. G., & Desloovere, K. (2016). Gait analysis: clinical facts. Eur J Phys Rehabil Med, 52(4), 560-574.

Burton, E., Cavalheri, V., Adams, R., Browne, C. O., Bovery-Spencer, P., Fenton, A. M., . . . Hill, K. D. (2015). Effectiveness of exercise programs to reduce falls in older people with dementia living in the community: a systematic review and meta-analysis. Clin Interv Aging, 10, 421-434. doi:10.2147/CIA.S71691

Carter, N. D., Kannus, P., & Khan, K. M. (2001). Exercise in the prevention of falls in older people: a systematic literature review examining the rationale and the evidence. Sports Med, 31(6), 427-438. doi:10.2165/00007256-200131060-00003

Dipietro, L., Campbell, W. W., Buchner, D. M., Erickson, K. I., Powell, K. E., Bloodgood, B., . . . Olson, R. D. (2019). Physical Activity, Injurious Falls, and Physical Function in Aging: An Umbrella Review. Med Sci Sports Exerc, 51(6), 1303-1313. doi:10.1249/mss.0000000000001942

Gillespie, L. D., Robertson, M. C., Gillespie, W. J., Sherrington, C., Gates, S., Clemson, L. M., & Lamb, S. E. (2012). Interventions for preventing falls in older people living in the community. Cochrane Database Syst Rev(9), Cd007146. doi:10.1002/14651858.CD007146.pub3

Lacroix, A., Hortobagyi, T., Beurskens, R., & Granacher, U. (2017). Effects of Supervised vs. Unsupervised Training Programs on Balance and Muscle Strength in Older Adults: A Systematic Review and Meta-Analysis. Sports Med, 47(11), 2341-2361. doi:10.1007/s40279-017-0747-6

McInnes, L., Gibbons, E., & Chandler-Oatts, J. (2005). Clinical practice guideline for the assessment and prevention of falls in older people. Worldviews Evid Based Nurs, 2(1), 33-36. doi:10.1111/j.1524-475X.2005.04094.x

Moniz-Pereira, V., Carnide, F., Machado, M., Andre, H., & Veloso, A. P. (2012). Falls in Portuguese older people: procedures and preliminary results of the study Biomechanics of Locomotion in the Elderly. Acta Reumatologica Portuguesa, 37(4), 324-332.

Panel on Prevention of Falls in Older Persons, A. G. S., & British Geriatrics, S. (2011). Summary of the Updated American Geriatrics Society/British Geriatrics Society clinical practice guideline for prevention of falls in older persons. J Am Geriatr Soc, 59(1), 148-157. doi:10.1111/j.1532-5415.2010.03234.x

Pothier, K., Gagnon, C., Fraser, S. A., Lussier, M., Desjardins-Crepeau, L., Berryman, N., . . . Bherer, L. (2018). A comparison of the impact of physical exercise, cognitive training and combined intervention on spontaneous walking speed in older adults. Aging Clinical and Experimental Research, 30(8), 921-925. doi:10.1007/s40520-017-0878-5

Raymond, M. J., Bramley-Tzerefos, R. E., Jeffs, K. J., Winter, A., & Holland, A. E. (2013). Systematic review of high-intensity progressive resistance strength training of the lower limb compared with other intensities of strength training in older adults. Arch Phys Med Rehabil, 94(8), 1458-1472. doi:10.1016/j.apmr.2013.02.022

Rikli, R. E., & Jones, C. J. (1999). Functional fitness normative scores for community-residing older adults, ages 60-94. Journal of Aging and Physical Activity, 7(2), 162-181. doi:https://doi.org/10.1123/japa.7.2.162

Rikli, R. E., & Jones, C. J. (2013). Senior fitness test manual (2nd ed.). Champaign, IL: Human Kinetics.

Ritt, M., Jager, J., Ritt, J., Sieber, C., & Gassmann, K. G. (2017). Analysis of a Frailty Index based on Routine Blood / Urine Parameters (FI-LAB) as a Frailty Screening Tool in inpatient geriatric Patients. Zeitschrift Fur Gerontologie Und Geriatrie, 50, S4-S4.

Ritt, M., Ritt, J. I., Sieber, C. C., & Gassmann, K. G. (2017). Comparing the predictive accuracy of frailty, comorbidity, and disability for mortality: a 1-year follow-up in patients hospitalized in geriatric wards. Clinical Interventions in Aging, 12, 293-304. doi:10.2147/Cia.S124342

Rose, D. J. (2010). Fallproof! : a comprehensive balance and mobility training program (2nd ed.). Champaign, IL: Human Kinetics.

Sanchis-Sanchis, R., Blasco-Lafarga, C., Encarnacion-Martinez, A., & Perez-Soriano, P. (2020). Changes in plantar pressure and spatiotemporal parameters during gait in older adults after two different training programs. Gait & Posture, 77, 250-256. doi:10.1016/j.gaitpost.2020.01.015

Schwenk, M., Zieschang, T., Englert, S., Grewal, G., Najafi, B., & Hauer, K. (2014). Improvements in gait characteristics after intensive resistance and functional training in people with dementia: a randomised controlled trial. Bmc Geriatrics, 14. doi:Artn 7310.1186/1471-2318-14-73

Shekelle, P., Maglione, M., Chang, J., Mojica, W., Shekelle, P. G., Maglione, M. A., . . . Lapin, P. (2003). Falls Prevention Interventions in the Medicare Population. In.

Sherrington, C., Fairhall, N. J., Wallbank, G. K., Tiedemann, A., Michaleff, Z. A., Howard, K., . . . Lamb, S. E. (2019). Exercise for preventing falls in older people living in the community. Cochrane Database Syst Rev, 1, CD012424. doi:10.1002/14651858.CD012424.pub2

Sherrington, C., Tiedemann, A., Fairhall, N., Close, J. C., & Lord, S. R. (2011). Exercise to prevent falls in older adults: an updated meta-analysis and best practice recommendations. N S W Public Health Bull, 22(3-4), 78-83. doi:10.1071/NB10056

Silva, N. L., Oliveira, R. B., Fleck, S. J., Leon, A. C., & Farinatti, P. (2014). Influence of strength training variables on strength gains in adults over 55 years-old: a meta-analysis of dose-response relationships. J Sci Med Sport, 17(3), 337-344. doi:10.1016/j.jsams.2013.05.009

Steib, S., Schoene, D., & Pfeifer, K. (2010). Dose-response relationship of resistance training in older adults: a meta-analysis. Med Sci Sports Exerc, 42(5), 902-914. doi:10.1249/MSS.0b013e3181c34465

Strandell, H., & Wolff, P. (2019). Aging Europe: Looking at the lives of older people in the EU. In Eurostat. Statistical editions, (pp. 162).

Van Abbema, R., De Greef, M., Craje, C., Krijnen, W., Hobbelen, H., & Van Der Schans, C. (2015). What type, or combination of exercise can improve preferred gait speed in older adults? A meta-analysis. Bmc Geriatrics, 15, 72. doi:10.1186/s12877-015-0061-9

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7- Thesis Related Outcomes

7.1- First author papers in scientific journals

- Ramalho F, Santos-Rocha R, Branco M, Moniz-Pereira V, André HI, Veloso AP, Carnide F. (2018). Effect of 6-month community-based exercise interventions on gait and functional fitness of an older population: a quasi-experimental study. Clin Interv Aging. 6;13:595-606. doi: 10.2147/CIA.S157224.
- Ramalho F, Carnide F, Santos-Rocha R, André HI, Moniz-Pereira V, Machado ML, Veloso AP. (2017). Community-Based Exercise Intervention for Gait and Functional Fitness Improvement in an Older Population: Study Protocol. J Aging Phys Act.;25(1):84-93. doi: 10.1123/japa.2015-0290.
- Ramalho F, Santos-Rocha R, Branco M, Morouço P, Carnide F. (2020). A Comprehensive Review on the Interaction Between Gait and Functional Capacity in Older Adults (submitted).

7.2- Co-author in papers in scientific journals

- André HI, Moniz-Pereira V, Ramalho F, Santos-Rocha R, Veloso A, Carnide F. (2020). Responsiveness of the Calf-Raise Senior test in community-dwelling older adults undergoing an exercise intervention program. PLoS One; 15(4):e0231556. doi: 10.1371/journal.pone.0231556. eCollection 2020. PubMed PMID: 32348321; PubMed Central PMCID: PMC7190110.
- Santos-Rocha R, Freitas J, Ramalho F, Pimenta N, Costa Couto F, Apóstolo J. (2019). Development and validation of a complex intervention: A physical exercise programme aimed at delaying the functional decline in frail older adults. Nurs Open. 2019 Sep 30;7(1):274-284. doi: 10.1002/nop2.388. eCollection 2020 Jan. PubMed PMID: 31871711; PubMed Central PMCID: PMC6917945.
- André HI, Carnide F, Moço A, Valamatos MJ, Ramalho F, Santos-Rocha R, Veloso AP (2018). Can the calf-raise senior test predict functional fitness in elderly people? A

validation study using electromyography, kinematics and strength tests. Phys Ther Sport;32:252-259. doi: 10.1016/j.ptsp.2018.05.012. PubMed PMID: 29883924.

- André HI, Carnide F, Borja E, Ramalho F, Santos-Rocha R, Veloso AP. (2016). Calf-raise senior: a new test for assessment of plantar flexor muscle strength in older adults: protocol, validity, and reliability. Clin Interv Aging; 2016 Nov 15;11:1661-1674. eCollection 2016. PubMed PMID: 27895473; PubMed Central PMCID: PMC5117878.
- Machado ML, Tavares C, Moniz-Pereira V, André HI, Ramalho F, Veloso AP, Carnide, F. (2016). Validation of YPAS-PT – The Yale Physical Activity Survey for Portuguese Older People, Science Journal of Public Health. Vol. 4, No. 1, pp. 72-80. doi: 10.11648/j.sjph.20160401.20
- Moniz-Pereira V, Carnide F, Ramalho F, André H, Machado M, Santos-Rocha R, Veloso AP. (2013). Using a multifactorial approach to determine fall risk profiles in portuguese older adults. Acta Reumatol Port.;38(4):263-72. PubMed PMID: 24435031.
- Moniz-Pereira V, Carnide F, Machado M, André H, Veloso AP. (2012). Falls in Portuguese Older People: Procedures and Preliminary results of the study Biomechanics of Locomotion in the Elderly, Acta Reumatológica Portuguesa 37, 4: 324-332.

7.3- First author communications at scientific meetings

Oral Communications

- Ramalho F, André H, Moniz-Pereira V, Machado M, Carnide F, Santos-Rocha R, Veloso AP. More Active Aging program: longitudinal effects on functional fitness parameters related to fall risk in Portuguese active elderly. Follow-up and comparison to other programs. 19th Annual Congress of the European College of Sport Sciences, Amsterdam, 2nd-5th July 2014.
- Ramalho F, André H, Moniz-Pereira V, Machado M, Carnide F, Santos-Rocha R, Veloso AP. MORE ACTIVE AGING Implementation of a lifestyle intervention in older adults, regarding functionality and other health outcomes – baseline results. 17th Annual Congress of the European College of Sport Sciences, Bruges, 4th-7th July 2012.

7.4- Community Dissemination

Booklets

Machado M, Moniz-Pereira V, Carnide F, André H, Ramalho F, Veloso A. GUIA PARA UM ENVELHECIMENTO MAIS ATIVO. 1.ª Ed. Lisboa: Laboratório de Biomecânica e Morfologia Funcional FMH-UTL, 2011 (ISBN: 979-989-97566-0-1).

Machado M, Moniz-Pereira V, Carnide F, André H, Ramalho F, Veloso A. GUIA PARA UM ENVELHECIMENTO MAIS ATIVO. 2.ª Ed. Lisboa: Laboratório de Biomecânica e Morfologia Funcional FMH-UTL, 2014 (ISBN: 979-989-97566-1-8) e Edições MAPFRE (ISBN: 979-989-99180-0-9).

André HI, Ramalho F. (2017). Aptidão Física e Ocorrência de Quedas em Idosos Praticantes de Exercícios Físicos In: Aspetos biopsicossociais do envelhecimento e a prevenção de quedas na terceira idade. 1.ª Ed. Joaçaba: Editora Unoesc, (ISBN 978-858422-145-5). http://www.unoesc.edu.br/images/uploads/editora/Aspectos_Biopsicossociais_do_envelhecimento.pdf

Santos-Rocha R, Freitas J, Ramalho F, Couto F, Apóstolo J. (2019). Programa de Exercício Físico para o Idoso com Fragilidade – Manual de Apoio. Unidade de Investigação em Ciências da Saúde: Enfermagem - Escola Superior de Enfermagem de Coimbra (ISBN: 978-989-99426-8-4)

Thesis Appendix

J Aging Phys Act. 2016 Sep 6:1-26. [Epub ahead of print]
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Community-Based Exercise Intervention for Gait and Functional Fitness Improvement in an Older Population: Study Protocol

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ABSTRACT

Functional fitness (FF) and gait ability in older populations have been associated with increased survival rates, fall prevention and quality of life. One possible intervention for the improvement of FF is well-structured exercise programs. However, there are inconsistent findings regarding the effects of exercise interventions in the maintenance of gait parameters. The aim of this protocol is to develop a community-based exercise intervention targeting an older population. The intervention aim is the improvement of gait parameters and FF. A control trial with follow-up will be performed. The primary outcome variables will be plantar pressure gait parameters. The secondary outcome variables will be aerobic endurance, lower limb strength, agility, and balance. These variables will be recorded at baseline and after 12, 24 and 36 weeks, in the intervention and control groups. If effective, this protocol can be used by exercise professionals in improving community exercise programs.

BACKGROUND

"Healthy aging" has traditionally focused on prevention disease, but greater efforts are needed to reduce frailty and dependency and maintain independent physical and cognitive function among older adults (Bauman, Merom, Bull, et al., 2016). Maintaining functional status and reducing age-related morbidity is an important part of active aging policies; it promotes independent living, improves the quality of life, and reduces health care costs (Chodzko-Zajko, Proctor, Fiatarone Singh, et al., 2009; Nelson, Rejeski, Blair, et al., 2007). A systematic review concluded that exercise programs reduce the age-related decline in functional capacity and maintain muscle strength and mass among adults aged 65–85 years (Paterson & Warburton, 2010). A 50% reduction in the relative risk of developing functional limitations or disability was reported among those participating in a moderate-intensity physical activity (PA) (Paterson & Warburton, 2010; Tak, Kuiper, Chorus, et al., 2013). The heterogeneity of the interventions and the fact that most of the studies were focused on clinical populations, leads to inconsistent results on outcomes (Chen, Lin, & Jiang, 2015; Conn, Valentine, & Cooper, 2002; Liu, Hu, Li, et al., 2011; Parmenter, Raymond, Dinnen, et al., 2011; Rubenstein, Josephson, Trueblood, et al., 2000; Thuné-Boyle, Iliffe, Cerga-Pashoja, et al., 2012; Tseng, Gau, & Lou, 2011).

In fact, gait variability and speed could be helpful in identifying different categories of frailty, despite the paucity of studies (Schwenk, Howe, Saleh, et al., 2014). However, the literature is not consistent in what is concerned with the effect of exercise on the maintenance of gait attributes in older people (Cadore, Rodríguez-Mañas, Sinclair, et al., 2013). Significant positive meta-effect of different types of exercise interventions from randomized controlled trials have been shown to improvement in preferred gait speed (Van Abbema, De Greef, Crajé, et al., 2015) and dual-task walking in older adults (Plummer, Zukowski, Giuliani, et al., 2015). Moreover, walking-based exercise may contribute to improved gait parameters (step cadence and length) in multiple sclerosis patients (Wonneberger & Schmidt, 2015). The information derived from plantar pressure measures is important in gait and posture research for diagnosing lower limb problems and injury prevention (Lee, Simmonds, Etnyre, et al., 2007; Razak, Zayegh, Begg, et al., 2012; Robinson, Balbinot, Silva, et al., 2013; Amemiya, Noguchi, Oe, et al., 2014), among other applications, such as analyzing the effects of a treatment or intervention (Parkatti, Perttunen, & Wacker, 2012; Iunes, Rocha, Borges, et al., 2014; Chen et al., 2015).

The purpose of this protocol is to develop a multi-component community-based exercise intervention ("More Active Ageing Program" - MAAP), organized in a group-based setting and aiming at the improvement of the gait attributes and functional fitness in a group of community living older people. The intervention to be tested consists of a periodized and controlled physical exercise program, based on the following components: (1) posture control, (2) balance (static and dynamic), (3) strength e agility of lower limbs, and (4) aerobic capacity. This rational is supported by the evidence of the positive impact of community exercise programs in the improvement of functional fitness attributes among elderly populations (Chase, 2015; Conn et al., 2002; Liu & Latham, 2009; 2011; Seco, Abecia, Echevarría, et al., 2012) and on the current guidelines for exercise and older adults (ACSM, 2013; King, Rejeski, & Buchner, 1998).

We hypothesized that this 9 months intervention will be effective for the improvement of the gait and functional fitness parameters of older participants, based on the fact that the majority of interventions reviewed were short-term (<6 months), and the differences between center-based class and other exercise approaches (e.g., home-based) were small; yet in "real world" settings, there is a substantial decline in attendance at center-based classes for seniors (Ecclestone, Myers, & Paterson, 1998; van der Bij, Laurant, & Wensing, 2002). The present study protocol describes the rationale, the design and the methods of the MAAP, as well as the test procedures, from baseline to three, six and nine months of intervention.

PARTICIPANTS AND METHODS

Design

The approach to the proposed study includes a 9 months follow-up intervention designed to test the effectiveness of a periodized and controlled exercise program effects on the gait and functional fitness parameters. The study will use a multicenter approach (Figure 1). An intervention group will receive a three-phased intervention with follow-up. Phase I (first cycle of 12 weeks) is characterized by the development of postural control and balance; Phase II (13 to 24 weeks) is focused on strength and muscle resistance improvement in lower limbs; and Phase III (25 to 36 weeks) is branded by the development of all fitness components. Other groups of older people (control group) will receive a non-periodized intervention with follow-up. The intervention will be carried out for 36 weeks, twice a week, for 50 min each session. The follow-up period will be 12, 24 and 36 weeks from the baseline condition.

The study will be conducted in partnership with the Sport Sciences School of Rio Maior – Polytechnic Institute of Santarém and the Neuromechanics of Human Movement Research Group of CIPER/Faculdade de Motricidade Humana, Universidade de Lisboa. This study received ethical approval by the Ethics Committee of the Faculty of Human Kinetics, University of Lisbon. A written informed consent will be obtained from all participants at the beginning of the intervention, before the allocation to the two groups (intervention or control groups).

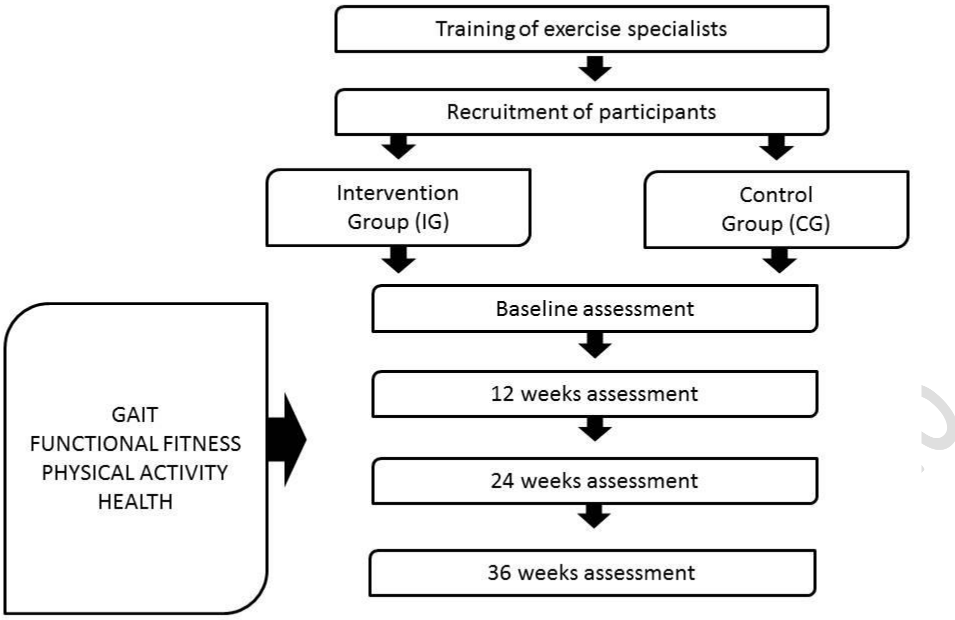

Figure 1 – Phases of the study

Intervention planning

Graduated exercise specialists will deliver all exercise sessions, and will use the same planning on all subgroup classes, in accordance with the recommendations of the American College of Sports Medicine (ACSM, 2013). After agreeing in taking part of the staff, the exercise specialists will attend to a 20h training program. This training is focused on the pedagogical aspects of each stage of the program, as well as on the assessment procedures.

Regarding the recruitment strategy, community-dwelling older adults will be recruited via: 1) advertisements in the local newspapers and community partner publications; 2) posters at local businesses; 3) health fairs; 4) and municipalities' website. Interested participants will be contacted by the project manager by phone, and a brief description of the study will be provided.

If responses suggest study eligibility then interested individuals will be invited to attend a formal in-person screening and then to participate in one of the community centers without any payment. The project manager will explain the objectives of the study, and answer all questions before asking the participant to consent the participation in the study. This planning will allow the follow-up record of complete data on the participants of both groups (intervention and control), as well as, analysis and comparisons of changes in the variables mentioned above.

Setting

The intervention will be implemented in community centers, in five municipalities of West and Ribatejo regions of Portugal allowing the recruitment of participants living in small towns and rural areas. Six community centers will be offering an exercise program. The MAAP will be implemented in three of these centers. The control group will be attending to an exercise program in the other three settings. The project manager will check the conditions of the locations, regarding the available equipment and safety.

Participants

The older adults will be engaged in the MAAP through the sports community services of the five municipalities. The project manager will call participants who show interest in participating, will give a verbal description of the study, will explain the risks and benefits of participating, and will ask for medical clearance for physical exercise. Participants will be considered eligible for the study if they are aged 65 years and older, community-dwelling living, understand the Portuguese language and agree to participate voluntarily in this study. The exclusion criteria will include: to have a neurologic condition (e.g., dementia or Parkinson disease), a cardiovascular condition (e.g., stroke), or other abnormality that would influence the ability to answer a questionnaire, neither speaking nor understanding the Portuguese language, to use a walking aid, presence of hip, knee or ankle prosthesis, or incapacity of performing exercises in the standing position. Participants will be randomly assigned to each intervention group (IG) or control group (CG) taking into account the geographical proximity of their homes and intervention settings, i.e., they will be given the opportunity to choose between, at least, two of the available settings. Both groups will include participants with similar characteristics regarding mean age, inclusion and exclusion criteria.

The calculation of the sample size is based on the detection of significant differences in individual's functional fitness score (over 3, 6 and 9 months) in MAAP group when compared to other exercise program group (CG). In order to detect a minimum effect size of 0.50, with power (1-B) set as 0.80 and alpha set at 0.05, 174 participants will be recruited from six regional centers. Assuming that this will be an intervention study with a loss to follow-up of 10%, the sample size will be 191 participants. The sample size calculation was based on both intention to treat and per protocol analysis (Gupta, 2011). The sample size was calculated on the expected results for the secondary variables (functional fitness parameters) since there are no data regarding gait parameters. The loss to follow-up will be calculated from the proportion of participants that will be randomly assigned to the intervention (*n*=96) and control groups (*n*=95) (Dettori, 2011). Moreover, participants with an attendance rate lower than 75% of the sessions in each of the programs' mesocycles will be excluded from the analysis.

Exercise Program

The MAAP was designed to focus specifically the postural stability, balance and strength in lower limbs, combined with aerobic exercise, at a level of intensity in accordance with the participants' functional capacities.

Balance and strength are two of the components of functional fitness, and have been related to physical risk factors related to falls (Carter, Kannus, & Khan, 2001; Kenny, Rubenstein, Tinetti, et al., 2011; McInnes, Gibbons, & Chandler-Oatts, 2005; Rose & Hernandez, 2010; Shekelle, Maglione, Chang et al., 2003; Sherrington, Tiedemann, Fairhall, et al., 2011; Skelton & Beyer, 2003). In this regard, Rose and Hernandez (2010) emphasized the specific relevance of incorporating multiple dimensions of balance in exercise sessions, using movements that challenge stability in standing positions and activities designed to improve sensory processing and integration, attention capacity and coordination. Regarding strength training, the relationship between its effects on fall prevention is not clear, despite the fact that muscle weakness in lower limbs is considered one of the most important fall risk factors (Carter et al., 2001; [no authors listed], 2001). This can be explained by the fact that the long-term benefits of strength training in the prevention of falls are not evident in trials with follow-ups of short duration (Sherrington et al., 2011). Nevertheless, the inclusion of strength and power training in lower limbs is recommended (ACSM, 2013; Rose & Hernandez, 2010; Skelton, Greig, Davies, et al., 1994) given its role in the mechanical efficiency of gait and relationship to functional tasks such as step climbing and obstacle crossing (McInnes et al., 2005).

These components (posture stability, balance and strength training) will be based on group exercise and circuit training. The aerobic component will be based on walking and mobility group exercise. The intervention group (IG) will be engaged in an exercise program that will be controlled, periodized and organized in three cycles of 12 weeks, according to the structure presented in table 1.

Table 1 – Structure of the exercise program of the intervention group

Phase and period	Aims, pattern and frequency	Features
Phase I (1 to 12 weeks)	Development of postural alignment and balance (static and dynamic). Pattern: sessions based on group exercise, including warm-up (5 min) and cool-down (5 min). Frequency: two sessions/week	Type: Aerobic exercise - mobility exercises of the lower limb and walking pattern training with a gradual increase in intensity and complexity, but not imposing excessive orthopedic stress. Duration: 20 min Intensity: 3-4 Foster Scale Progression: 4-5 Foster Scale
		Type: Postural alignment - exercise routines, following postural and Pilates-based techniques will be used to develop body awareness, breathing patterns control, core muscles conditioning integrated with upper and lower limbs coordination performed in different body positions (lying down sitting and cat position). Duration: 10 min
		Type: Balance – sets of exercises performed in the standing position and based on functional training and Tai Chi techniques with controlled steps and weight shifts, progressing from stable to less stable base of support, in order to improve the center of mass control. Duration: 10 min
Phase II (13 to 24 weeks)	Improvement of strength and muscle resistance in lower limbs. Pattern: sessions based on group exercise and interval training, including warm-up (5 min) and cool-down (5 min). Frequency: two sessions/week	Type: Aerobic exercise - mobility exercises of the lower limb and walking pattern training with a gradual increase in intensity and complexity, but not imposing excessive orthopedic stress. Duration: 20 min Intensity: 4-5 Foster Scale Progression: 5-6 Foster Scale
		Type: Strength and muscle resistance in lower limbs, and core stability - using exercises with additional loads and elastic resistance as well as movements that progressively increase support instability and the integration of whole body movements (upper and lower limbs, together with core stability). Duration: 10 min Intensity: 10-15 repetitions (strength); 15-20 repetitions (muscular endurance); 2 sets Progression: greater resistance and set of repetitions
		Type: Dynamic Balance – sets of exercises performed using dynamic positions such as changing direction, velocity, and planes of movement, and functional training, in order to improve the center of mass control. Duration: 10 min
Phase III (25 to 36 weeks)	Maintenance of fitness components and the integration of whole body movements (upper and lower limbs, together with core stability). . Pattern: sessions based on circuit training, including warm-up (5 min) and cool-down (5 min). Frequency: two sessions/week	Type: Aerobic exercise - mobility exercises of the lower limb and walking pattern training with a gradual increase in intensity and complexity, but not imposing excessive orthopedic stress. Duration: 20 min Intensity: 4-5 Foster Scale Progression: 5-6 Foster Scale
		Type: Strength and muscle resistance in lower limbs, and core stability - using exercises with additional loads and elastic resistance as well as movements that progressively increase support instability and the integration of whole body movements (upper and lower limbs, together with core stability). Duration: 10 min Intensity: 10-15 repetitions (strength); 15-20 repetitions (muscular endurance); 2-3 sets Progression: greater resistance and set of repetitions
		Type: Dynamic Balance – sets of exercises performed using dynamic positions such as changing direction, velocity, and planes of movement, and functional training, in order to improve the center of mass control. Duration: 5 min
		Type: Flexibility will also be integrated into training programs, aimed at the maintenance or improvement of the joint mobility within the healthy limits. Duration: 5 min Intensity: static stretch to the point of feeling slight discomfort; hold a stretch for 30-60 s.

The IG exercise program will follow a linear periodization to provide weekly progressive modifications in intensity and complexity, and to change the type of exercises monthly, considering the pre-defined objectives for each part of the session, based on the training principles of overload, progression, and variability (Bompa & Haff, 1999). Each exercise should be specifically designed to have alternative options to the participants' limitations (e.g., difficulties to perform an exercise in kneeling or lying position), and to evolve from the functional fitness level of the participants. Monthly checklists will be created to confirm if the target goals defined for each type of exercise (postural control, balance, and strength) are being achieved according to the predefined program. With these checklists, instructors should verify the percentage of participants who correctly performed the exercises and then report the results to the researchers, to make the necessary adjustments in planning. The control group (CG) will be engaged in an exercise program described in table 2.

Table 2 – Structure of the exercise program of the control group

<table>
<tr><th>Period</th><th>Aims, pattern and frequency</th><th>Features</th></tr>
<tr><td rowspan="2">(1 to 36 weeks)</td><td rowspan="2">Development and maintenance of fitness components and the integration of whole body movements

Pattern: sessions based on group exercise, including warm-up (5 min) and cool-down (5 min).

Frequency: two sessions/week</td><td>Type: Aerobic exercise - mobility exercises of the lower limb and walking pattern training with a gradual increase in intensity and complexity, but not imposing excessive orthopedic stress.
Duration: 25 min
Intensity: 3-4 Foster Scale
Progression: 4-5 Foster Scale</td></tr>
<tr><td>Type: Strength and muscle resistance in lower limbs, and core stability - using exercises with additional loads and elastic resistance as well as movements that progressively increase support instability and the integration of whole body movements (upper and lower limbs, together with core stability).
Duration: 15 min
Intensity: 10-15 repetitions (strength); 15-20 repetitions (muscular endurance); 2-3 sets
Progression: greater resistance and set of repetitions</td></tr>
</table>

The main differences between the CG and the IG programs are: the planning of training variation (periodization) in 3 mesocycles; the introduction of postural alignment in the first 12 weeks; the introduction of balance training in the three phases; and the class design during phase 3 (circuit training). Both programs will last 36 weeks and will comprise group-based 50 min exercise sessions twice a week. Also, they will be delivered by different instructors. In both programs, the exercise intensity will be controlled by using the Rate of Perceived Exertion scale of Foster, Florhaug, Franklin, et al. (2001) and participants will be encouraged to exercise at a level that they felt 4 (somewhat hard) to 6 (hard) (Day, McGuigan, Brice, et al., 2004).

The participation of all subjects (IG and CG) will be controlled through attendance forms. The integrity of the intervention will be assessed by observation of two randomly selected sessions per month. The project manager will use a checklist to score sessions based on content identified in the intervention protocol. Drift will be defined as teaching less than 80% of the protocol content. If drift occurs, the examiner will be re-trained until the protocol is followed consistently. A checklist of behavioral indicators will be used to assess the examiner's skills in facilitating sessions, engaging the participants, problem-solving, providing positive feedback, and goal setting. Retraining will be provided as necessary.

Plantar Pressure Gait Assessment

Key plantar pressure parameters will be recorded as subjects walked barefoot across a 10 m walkway placed on the floor, at self-determined velocity. The subjects will be allowed to acclimatize to the equipment by performing few trials before data collection. Five stances from each foot from each participant will be collected. Plantar pressure data will be obtained using a Novel emed-x system (Münich, Germany). The primary outcome variables will be the gait parameters that are described in table 3. Data will be collected using a high sensor resolution mode with a sensor resolution of 4 sensors/cm^2 and a frame rate of 100 Hz. The Novel software will be used for data analysis. Force data will be normalized to the body weight (BW) allowing comparisons. To our knowledge, there is no other study which has investigated the usefulness of these data as a measure of the effect of an exercise intervention in an independent older population.

Functional Fitness Assessment

Functional Fitness (FF) tests (Rikli & Jones, 1999; 2013; Rose, Lucchese, & Wiersma, 2006) will be administered by trained examiners after engaging in a training workshop, which previously demonstrated a high inter-observer agreement for all FF tests (Moniz-Pereira et al., 2012).

Three tests from the "Senior Fitness Tests" (SFT) battery (Rikli & Jones, 1999; 2013) will be used to assess strength and mobility variables (table 3). Both dynamic and static balance will be evaluated through two tests each, from "Fullerton Advanced Balance Scale" (Rose et al., 2006). A total balance score (BTS) will be computed by the sum of the results from dynamic and static balance. The outcome measure Total Functional Fitness Score (TFFS) is a composite variable which can provide a comprehensive overview of the effects of this intervention (since it reflects the most important physical parameters related to intrinsic risk factors for falls in older people). Those tests have shown to be good predictors of falls and functional decline in community-living older adults (Hernandez & Rose, 2008; Rose et al. 2006; Rose, 2015; Sherrington et al., 2011).

Demographics, Health, and Physical Activity Assessment

The covariates will include: demographics, health and falls parameters, physical activity levels and body composition measures (table 3).

Health status and falls prevalence will be assessed by a questionnaire designed and validated for Portuguese Language and Culture (Valente, 2012). The first part of the questionnaire includes questions about demographics. The second part is related to self-perception of health and falls. The history of falls was defined as the experience of any falls during the period before assessments (previous 12 months at baseline and three months during the follow-up period).

Physical activity (PA) profiles will also be evaluated by a short version of "Yale Physical Activity Survey" (YPAS) (Dipietro, Caspersen, Ostfeld, et al., 1993), which allows defining 6 distinct PA dimensions: 1) Vigorous activity; 2) Leisurely walking; 3) Moving; 4) Standing; and 5) Sitting; and a PA total score, considering a typical week of the previous month. This questionnaire was validated for the Portuguese population (Machado, Tavares, Moniz-Pereira, et al., 2016).

Both questionnaires will be administered by face-to-face interviews involving the same trained examiners. The procedures are described elsewhere (Moniz-Pereira et al., 2012). Weight and height will be recorded to allow the calculation of body mass index (BMI).

Variables

The independent variables will be the features (type, duration, frequency, intensity and progression) of the exercise programs. The primary and secondary outcome variables and the covariables that will be recorded before the intervention (baseline), and after 12, 24 and 36 weeks of intervention, in the intervention and control groups, are described in table 3.

Table 3 – Primary and secondary outcome variables and covariables

Primary Outcome Variables	
Gait parameters	• Applied local force-maximum vertical ground reaction force (GRF); • Total force in an anatomical foot area (TOF); • Maximum and mean applied local pressure (PPM and PPm); • Pressure-time integral (PTI); • Force-time integral in an anatomical area (FTI); • Force-time integral timing of foot loading (TFL); • Deformation of the foot during loading (DFL).
Secondary Outcome Variables	
Functional fitness parameters	• Lower body strength • Agility • Aerobic endurance • Dynamic balance Static balance
Covariables	
Health and falls parameters	• Age; • Gender; • Scholarity; • Living alone • Health (HPS) self-perception status; • Medication intake (Meds); • Fear of falling (FOF); • Falls prevalence (FP).
Physical Activity parameters	• Vigorous activity; • Walking activity; • Moving activity • Standing activity • Time spent in sitting position; • Total activity.
Body composition parameters	• Body mass index.

Data Management and Analysis

Participants will be tracked using ID numbers. All data will be entered by a researcher into a Statistical Package for Social Sciences (SPSS) database and backed up on a secure central computer network system. Data will undergo range, consistency, and outlier checks.

Statistical analysis will be performed to obtain descriptive statistics and to evaluate the effectiveness of the MAAP on the improvement of gait and functional fitness parameters in the intervention group, when compared to the program ministered to the control group. Data normality distribution will be checked with the Kolmogorov-Smirnov test. Independent sample t-tests will be performed to compare continuous outcomes between groups (IG versus CG). Chi-square Test will be used for demographics and covariables with nominal classification. Repeated Measures two-way analysis of variance (ANOVA) (2X3) with Huynh-Feldt correction will be performed to: 1) analyze the longitudinal changes within each group, regarding primary and secondary outcomes, and 2) to test the main effects of the intervention period (baseline to 12/24/36 weeks) and group interactions (IG versus CG) on the same outcomes. Polynomial contrasts will be used to verify linear and quadratic trends in reported changes. Significant interactions will be examined using single contrasts (first) to determine if effects are greater in the intervention or control group. The models will be design adjusted for covariables effects. Data will be analyzed using the SPSS (version 3.0) and statistical significance will be set at $p < .05$.

DISCUSSION

This study protocol aims to describe the rationale, the design, and the methods of the "More Active Ageing Program". The aim of the program is the improvement of gait and functional fitness parameters. We hypothesized that a well-periodized community program, in terms of the type of exercise and intensity progression, will have significantly better results in the improvement of gait and functional fitness parameters within the older population, than a non-periodized program.

The study will provide insight of the efficacy of a 36-week periodized intervention, and the results of the study will provide crucial information on the feasibility of delivering the intervention to the older population. Moreover, the exercise program is safe and targeted to the physical fitness levels and limitations of the participants, suggesting its usefulness as a means of health promotion among older adults.

The long-term effectiveness of this intervention will be established at the level of general mobility by means of adopting an active lifestyle, which can be translated into long-term effects in prevention of falls (Gillespie, Robertson, Gillespie, et al., 2012). In addition, this intervention aims to transfer these gains to the functional and independent living, and may result in an improved impact on participants' quality of life, and lower public health costs. If it shows any benefit, this protocol can be promoted in clinical practice and can be indicated as a complementary treatment for functional decline. Moreover, if effective in slowing functional decline, this protocol can be used by exercise professionals in improving community exercise programs.

The potential limitations of this study might be the difficulties of randomization of the groups since older people will be keener on participating in the program in a more convenient setting (i.e., not far from home). In addition, the exercise specialists of the CG will not be blind to the objectives of the intervention, thus, they may give some emphasis on balance training and, therefore, promote the development of this ability as in the intervention group. The time-consuming events related to the assessment of different variables will require extra time and planning, in addition to other activities related to the exercise program, requiring the attendance of the participants.

The major strength of this study will be the development and implementation of an exercise program, combining the advantages of a community group program with the efficacy of controlled and periodized exercise and a progressive stimulus tailored to participant's functional fitness level and musculoskeletal limitations. Although the evidence of its efficacy in fall prevention is promising, it remains unclear which specific features (i.e., type, intensity, frequency, duration and progression) are needed so that these programs can be effective in the improvement of functional fitness and gait parameters, and consequently, on the reduction of risk of falling in the long term (Rose & Hernandez, 2010; Skelton & Beyer, 2003). On the other hand, it has been shown that long-term benefits are not evident in trials of short duration (Sherrington et al., 2011). Herein, we present a more comprehensive, more specific and long duration exercise intervention for gait and functional fitness improvement in an older population, by periodizing selected postural, balance, strength and walking tasks, focusing on group exercise and circuit training.

Besides increased body weight (Butterworth, Landorf, Gilleard, et al., 2014), other factors have been associated with high levels of plantar pressure generated during gait (i.e., peak pressure and pressure-time integral), such as foot structure (O'Brien & Tyndyk, 2014), foot pain and risk of falls (Mickle et al., 2010), and walking strategy (Sullivan, Burns, Adams, et al., 2015). If one limitation of an extensive biomechanical analysis is the requirement of expensive laboratory equipment, in this case, the existing portable equipment to collect force data can be used in the same setting where the exercise intervention and the other assessments will take place.

Finally, another strength of this program is the ecological perspective to be used. The intervention will be adapted to the typical community-based programs offered in rural areas and small towns to the older population. Community group-based classes using multiple component exercises are the most popular programs attended by older people and provide health and psychosocial benefits which may contribute to compliance and long-term maintenance.

References

ACSM (2013). *ACSM's Guidelines for Exercise Testing and Exercise Prescription* (9th ed.). Philadelphia: Wolters Kluwer/ Lippincott, Williams and Wilkins. (ISBN-10: 1609136055; ISBN-13: 978-1609136055).

Amemiya, A., Noguchi, H., Oe, M., Ohashi, Y., Ueki, K., Kadowaki, T., Mori, T., & Sanada, H. (2014). Elevated plantar pressure in diabetic patients and its relationship with their gait features. *Gait and Posture, 40*(3), 408-414. PubMed doi: 10.1016/j.gaitpost.2014.05.063.

Bauman, A., Merom, D., Bull, F., Buchner, D., Singh, M.F. (2016) Updating the Evidence for Physical Activity: Summative Reviews of the Epidemiological Evidence, Prevalence, and Interventions to Promote "Active Aging". *The Gerontologist; 56* (S2) S268–S280. PubMed doi: 10.1093/geront/gnw031

Bompa, T.O., & Haff, G. (1999). *Periodization: Theory and Methodology of Training*. Champaign, IL: Human Kinetic. (ISBN-13: 9780736074834)

Butterworth, P.A., Landorf, K.B., Gilleard, W., et al. (2014). The association between body composition and foot structure and function: a systematic review. *Obesity Reviews, 15*(4), 348-357. PubMed doi: 10.1111/obr.12130.

Cadore, E.L., Rodríguez-Mañas, L., Sinclair, A., et al. (2013). Effects of different exercise interventions on risk of falls, gait ability, and balance in physically frail older adults: a systematic review. *Rejuvenation Research, 16*(2), 105-114. PubMed doi: 10.1089/rej.2012.1397.

Carter, N.D., Kannus, P., & Khan, K.M. (2001). Exercise in the prevention of falls in older people: a systematic literature review examining the rationale and the evidence. *Sports Medicine, 31*(6), 427-438. PubMed doi: 0112-1642/01/0006-0427.

Chase, J.-A. D. (2015). Interventions to increase physical activity among older adults: A meta-analysis. *The Gerontologist, 55*, 706–718. PubMed doi:10.1093/geront/gnu090

Chen, M.S., Lin, T.C., & Jiang, B.C. (2015). Aerobic and resistance exercise training program intervention for enhancing gait function in elderly and chronically ill Taiwanese patients. *Public Health, 129*(8), 1114-1124. PubMed doi: 10.1016/j.puhe.2015.04.018.

Chodzko-Zajko, W.J., Proctor, D.N., Fiatarone Singh, M.A., et al. (2009). American College of Sports Medicine position stand. Exercise and Physical Activity for Older Adults. *Medicine & Science in Sports & Exercise, 41*(7), 1510-1530. PubMed 1510.1249/MSS.1510b1013e3181a1510c1595c.

Conn, V. S., Valentine, J. C., & Cooper, H. M. (2002). Interventions to increase physical activity among aging adults: A meta-analysis. *Annals of Behavioral Medicine*, *24*(3), 190–200. PubMed doi:10.1207/S15324796ABM2403_04

Day, M.L., McGuigan, M.R., Brice, G., et al. (2004). Monitoring exercise intensity during resistance training using the session RPE scale. *Journal of Strength and Conditioning Research, 18*(2), 353-358. PubMed

Dettori, J.R. (2011). Loss to follow-up. *Evidence-Based Spine-Care Journal, 2*(1), 7-10. PubMed doi: 10.1055/s-0030-1267080.

Dipietro, L., Caspersen, C.J., Ostfeld, A.M., et al. (1993). A survey for assessing physical activity among older adults. *Medicine & Science in Sports & Exercise, 25*(5), 628-642. PubMed

Ecclestone, N. A., Myers, A. M., & Paterson, D. H. (1998). Tracking older participants of twelve physical activity classes over a three-year period. *Journal of Aging and Physical Activity, 6*, 70–82.

Foster, C., Florhaug, J.A., Franklin, J., Gottschall, L., Hrovatin, L.A., Parker, S., Doleshal, P., Dodge, C. (2001). A new approach to monitoring exercise training. *Journal of Strength and Conditioning Research, 15*(1):109-15. PubMed

Gillespie, L.D., Robertson, M.C., Gillespie, W.J., Sherrington, C., Gates, S., Clemson, L.M., & Lamb, S.E. (2012). Interventions for preventing falls in older people living in the community. *The Cochrane Database of Systematic Reviews,* Sep 12;9:CD007146. PubMed doi: 10.1002/14651858.CD007146.pub3.

Gupta, S.K. (2011). Intention-to-treat concept: A review. *Perspectives in Clinical Research, 2*(3): 109–112. PubMed doi: 10.4103/2229-3485.83221

Hernandez, D., & Rose, D.J. (2008). Predicting which older adults will or will not fall using the Fullerton Advanced Balance scale. *Archives Physical Medicine and Rehabilitation, 89*(12), 2309-2315. PubMed doi: 10.1016/j.apmr.2008.05.020.

Iunes, D.H., Rocha, C.B., Borges, N.C., Marcon, C.O., Pereira,V.M., & Carvalho, L.C. (2014). Self-care associated with home exercises in patients with type 2 diabetes mellitus. *PLoS One, 5*, 9(12):e114151, eCollection 2014. PubMed doi: 10.1371/journal.pone.0114151.

Kenny, R., Rubenstein, L.Z., Tinetti, M.E., et al. (2011). Summary of the updated American Geriatrics Society/British Geriatrics Society clinical practice guideline for prevention of falls in older persons. *Journal of the American Geriatrics Society, 59*(1), 148-157. PubMed doi: 10.1111/j.1532-5415.2010.03234.x.

King, A. C., Rejeski, W. J., & Buchner, D. M. (1998). Physical activity interventions targeting older adults: A critical review and recommendations. *American Journal of Preventive Medicine, 15*(4), 316–333. PubMed doi: 10.1016/S0749-3797(98)00085-3

Lee, C.E., Simmonds, M.J., Etnyre, B.R., & Morris, G.S. (2007). Influence of pain distribution on gait characteristics in patients with low back pain: part 1: vertical ground reaction force. *Spine (Phila Pa 1976), 20*, 32(12):1329-1336. PubMed

Liu, C.J. & Latham, N.K. (2011). Can progressive resistance strength training reduce physical disability in older adults? A meta-analysis study. *Disability and Rehabilitation, 33*(2):87-97. PubMed doi: 10.3109/09638288.2010.487145.

Liu, C.J. & Latham, N.K. (2009). Progressive resistance strength training for improving physical function in older adults. *Cochrane Database of Systematic Reviews, 3*, CD002759. PubMed doi:10.1002/14651858.

Liu, Y., Hu, F., Li, D., et al. (2011). Does physical activity reduce the risk of prostate cancer? A systematic review and meta-analysis. *European Urology*, *60*(5), 1029-1044. PubMed doi: 10.1016/j.eururo.2011.07.007.

Machado, M., Tavares, C., Moniz-Pereira, V., André, H., Ramalho, F., & Veloso, A. (2016). Validation of YPAS-PT – The Yale Physical Activity Survey for Portuguese Older People. *Science Journal of Public Health*, *4*(1), 72–80. http://doi.org/10.11648/j.sjph.20160401.20

McInnes, L., Gibbons, E., & Chandler-Oatts, J. (2005). Clinical practice guideline for the assessment and prevention of falls in older people. *Worldviews Evidence Based Nursing, 2*(1), 33-36. PubMed doi: 10.1111/j.1524-475X.2005.04094.x

Mickle, K.J., Munro, B.J., Lord, S.R., et al. (2010). Foot pain, plantar pressures, and falls in older people: a prospective study. *Journal of the American Geriatrics Society, 58*(10), 1936-1940. PubMed doi: 10.1111/j.1532-5415.2010.03061.x.

Moniz-Pereira, V., Carnide, F., Machado, M., et al. (2012). Falls in Portuguese older people: procedures and preliminary results of the study Biomechanics of Locomotion in the Elderly. *Acta Reumatológica Portuguesa, 37*, 324-332. PubMed

Nelson, M. E., Rejeski, W. J., Blair, S. N., Duncan, P. W., Judge, J. O., King, A. C., Macera, C. A., & Castaneda-Sceppa, C. (2007). Physical activity and public health in older adults: Recommendation from the American College of Sports Medicine and the American Heart Association. *Medicine and Science in Sports and Exercise, 39*(8), 1435–1445. PubMed doi:10.1249/mss.0b013e3180616aa2

O'Brien, D.L., & Tyndyk, M. (2014). Effect of arch type and Body Mass Index on plantar pressure distribution during stance phase of gait. *Acta of Bioengineering and Biomechanics, 16*(2), 131-135. PubMed doi: 10.5277/abb140215

Parkatti, T., Perttunen, J., & Wacker, P. (2012). Improvements in functional capacity from Nordic walking: a randomized-controlled trial among elderly people. *Journal of Aging and Physical Activity*, *20*(1), 93-105 PubMed

Parmenter, B.J., Raymond, J., Dinnen, P., et al. (2011). A systematic review of randomized controlled trials: Walking versus alternative exercise prescription as treatment for intermittent claudication. *Atherosclerosis*, *218*(1), 1-12. PubMed doi: 10.1016/j.atherosclerosis.2011.04.024.

Paterson, D.H., & Warburton, D.E. (2010). Physical activity and functional limitations in older adults: a systematic review related to Canada's Physical Activity Guidelines. *International Journal of Behavioral Nutrition and Physical Activity*, *11*(7):38. PubMed doi: 10.1186/1479-5868-7-38.

Plummer, P., Zukowski, L.A., Giuliani, C., et al. (2015). Effects of Physical Exercise Interventions on Gait-Related Dual-Task Interference in Older Adults: A Systematic Review and Meta-Analysis. *Gerontology*, *62*(1):94-117. PubMed doi:10.1159/000371577.

Razak, A.H.A., Zayegh, A., Begg, R.K., & Wahab, Y. (2012). Foot Plantar Pressure Measurement System: A Review. *Sensors (Basel)*, *12*, 9884-9912. PubMed doi:10.3390/s120709884.

Rikli, R.E., & Jones, C.J. (1999). Development and validation of a functional fitness test for community-residing older adults. *Journal of Aging and Physical Activity*, *7*(2), 129-161.

Rikli, R.E., & Jones, C.J. (2013). *Senior Fitness Test Manual* (2nd ed.). Champaign, IL: Human Kinetics. (ISBN-13: 9781450411189)

Robinson, C.C., Balbinot, L.F., Silva, M.F., Achaval, M., & Zaro, M.A. (2013). Plantar pressure distribution patterns of individuals with prediabetes in comparison with healthy individuals and individuals with diabetes. *Journal of Diabetes Sciences and Technology*, *7*(5), 1113-1121. PubMed

Rose, D., & Hernandez, D. (2010). The role of exercise in fall prevention for older adults. *Clinical Geriatrics Medicine*, *26*, 607-631. PubMed doi: 10.1016/j.cger.2010.07.003.

Rose, D.J. (2015). *Fallproof!: a comprehensive balance and mobility training program* (2nd ed.). Champaign, IL: Human Kinetics. (ISBN-13: 9781492527848)

Rose, D.J., Lucchese, N., & Wiersma, L.D. (2006). Development of a multidimensional balance scale for use with functionally independent older adults. *Archives of Physical Medicine and Rehabilitation*, *87*(11), 1478-1485. PubMed doi: 10.1016/j.apmr.2006.07.263.

Rubenstein, L.Z., Josephson, K.R., Trueblood, P.R., et al. (2000). Effects of a group exercise program on strength, mobility, and falls among fall-prone elderly men. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *55*(6), M317-M321. PubMed doi: 10.1093/gerona/55.6.M317

Schwenk, M., Howe, C., Saleh, A., et al. (2014). Frailty and technology: a systematic review of gait analysis in those with frailty. *Gerontology*, *60*(1), 79-89. PubMed doi: 10.1159/000354211.

Seco, J., Abecia, J.C., Echevarría, E., et al. (2012). A long-term physical activity training program increases strength and flexibility, and improves balance in older adults. *Journal of Aging and Physical Activity*, *38*, 37-47. PubMed doi: 10.1002/rnj.64.

Shekelle, P.G., Maglione, M.A., Chang, J.T., et al. (2003). Falls prevention interventions in the Medicare population. Santa Monica, CA: RAND Corporation. http://www.rand.org/pubs/reprints/RP1230.

Sherrington, C., Tiedemann, A., Fairhall, N., et al. (2011). Exercise to prevent falls in older adults: an updated meta-analysis and best practice recommendations. *New South Wales Public Health Bulletin*, *22*(4), 78-83. PubMed doi: 10.1071/NB10056.

Skelton, D., & Beyer, N. (2003). Exercise and injury prevention in older people. *Scandinavian Journal of Medicine and Science in Sports*, *13*(1), 77-85. PubMed doi: 10.1034/j.1600-0838.2003.00300.x

Skelton, D., Greig, C., Davies, J., et al. (1994). Strength, power and related functional ability of healthy people aged 65–89 years. *Age & Ageing*, *23*(5), 371-377. PubMed

Sullivan, J., Burns, J., Adams, R., et al. (2015). Plantar heel pain and foot loading during normal walking. *Gait & Posture*, *41*(2), 688-693. PubMed doi: 10.1016/j.gaitpost.2015.01.025.

Tak, E., Kuiper, R., Chorus, A., Hopman-Rock, M. (2013). Prevention of onset and progression of basic ADL disability by physical activity in community dwelling older adults: a meta-analysis. *Ageing Research Reviews*, *12*(1):329-38. PubMed doi: 10.1016/j.arr.2012.10.001.

Thuné-Boyle, I.C., Iliffe, S., Cerga-Pashoja, A., et al. (2012). The effect of exercise on behavioral and psychological symptoms of dementia: towards a research agenda. *International Psychogeriatrics*, *24*(7), 1046-1057. PubMed doi: 10.1017/S1041610211002365.

Tseng, C.N., Gau, B.S., & Lou, M.F. (2011). The effectiveness of exercise on improving cognitive function in older people: a systematic review. *Journal of Nursing Research*, *19*(2), 119-131. PubMed doi: 10.1097/JNR.0b013e3182198837.

Valente, S. (2012). Validação de um questionário de saúde e identificação de factores de risco de quedas para a população idosa portuguesa [Validation of a health questionnaire and identification of fall risk factors among the

Portuguese older population] (Master Thesis). Faculdade de Motricidade Humana - Universidade Técnica de Lisboa, Cruz-Quebrada.

Van Abbema, R., De Greef, M., Crajé, C., et al. (2015). What type, or combination of exercise can improve preferred gait speed in older adults? A meta-analysis. *BMC Geriatrics, 15*(1), 72. PubMed doi: 10.1186/s12877-015-0061-9.

van der Bij, A.K., Laurant, M.G., & Wensing, M. (2002). Effectiveness of physical activity interventions for older adults: a review. *American Journal of Preventive Medicine,* 22(2):120-33. PubMed doi: 10.1016/S0749-3797(01)00413-5

Wonneberger, M., & Schmidt, S. (2015). Changes of gait parameters following long-term aerobic endurance exercise in mildly disabled MS patients: an exploratory study. *European Journal of Physical Rehabilitation and Medicine, 51*(6):755-62. PubMed

[no authors listed] (2001). Guideline for the prevention of falls in older persons. American Geriatrics Society, British Geriatrics Society, and American Academy of Orthopaedic Surgeons Panel on Falls Prevention. *Journal of the American Geriatrics Society, 49*(5), 664-672. PubMed doi: 10.1046/j.1532-5415.2001.49115.x

FIGURE AND TABLE LEGENDS

Figure 1 – Phases of the study

Table 1 – Structure of the exercise program of the intervention group

Table 2 – Structure of the exercise program of the control group

Table 3 – Primary and secondary outcome variables and covariables

Clinical Interventions in Aging
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ORIGINAL RESEARCH

Effect of 6-month community-based exercise interventions on gait and functional fitness of an older population: a quasi-experimental study

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Background: Gait ability in older adults has been associated with independent living, increased survival rates, fall prevention, and quality of life. There are inconsistent findings regarding the effects of exercise interventions in the maintenance of gait parameters.
Objectives: The aim of the study was to analyze the effects of a community-based periodized exercise intervention on the improvement of gait parameters and functional fitness in an older adult group compared with a non-periodized program.
Methods: A quasi-experimental study with follow-up was performed in a periodized exercise group (N=15) and in a non-periodized exercise group (N=13). The primary outcomes were plantar pressure gait parameters, and the secondary outcomes were physical activity, aerobic endurance, lower limb strength, agility, and balance. These variables were recorded at baseline and after 6 months of intervention.
Results: Both programs were tailored to older adults' functional fitness level and proved to be effective in reducing the age-related decline regarding functional fitness and gait parameters. Gait parameters were sensitive to both the exercise interventions.
Conclusion: These exercise protocols can be used by exercise professionals in prescribing community exercise programs, as well as by health professionals in promoting active aging.
Keywords: mobility, community exercise programs, active aging, plantar pressure analysis, ground reaction forces, gait properties

Plain language summary

Gait ability is related to mobility, which is a critical variable in maintaining independent living in older adults. Moreover, gait ability has been associated with increased survival rates, fall prevention, and quality of life of older adults. There is evidence that physical exercise interventions may prevent falls and improve the overall fitness. This raised the possibility that exercise would be effective in the maintenance of selected gait parameters. We implemented two types of exercise interventions for 6 months, in two groups of older adults to verify whether they would have a positive effect in maintaining plantar pressure gait parameters and functional fitness. Moreover, we compared these two exercise interventions to verify which would be more effective. We conclude that both the programs are proved to be effective in reducing the age-related decline regarding functional fitness and gait parameters. Effective exercise protocols can be used by exercise professionals in prescribing community exercise programs, as well as by health professionals in promoting active aging.

Introduction

Gait ability in older adults has been associated with increased survival rates, fall prevention, and quality of life.[1] The changes in the structure and function of the foot are associated with aging and have considerable implications for the well-being of

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the older adult.[1] Gait ability is related to mobility, which in turn, is a critical variable in maintaining independence in older adults.[2] Furthermore, the functional status of older adults promotes independent living, improves the quality of life, and reduces health care costs.[1] Moreover, gait variability and speed can also help in identifying different categories of frailty.[3]

The information derived from podobarometric measures is important in gait and posture research for diagnosing lower limb problems and injury prevention.[4] Several factors have been associated with high levels of plantar pressure (ie, peak pressure and pressure–time integral [PTI]) generated during gait, such as increased body weight (BW) and foot structure (arch type),[5] foot pain and risk of falls,[6] active diabetic foot ulcers,[7] and walking strategy.[8]

Exercise is considered a key intervention for improving physical function in older adults.[9] It is well established in the literature that exercise programs reduce the age-related decline in functional capacity and maintain muscle strength and mass among adults aged 65–85 years.[10] It is expected that 50% of reduction in the relative risk of developing functional limitations or disability was reported among those participating in a moderate-intensity physical activity (PA),[10] as well as the improvement of functional fitness (FF) parameters.[11,12]

Recently, Wonneberger and Schmidt[13] suggested that a walking-based exercise may contribute to improve step cadence and step length in multiple sclerosis patients, and Wang et al[9] proved that short-term combined exercise improves gait performance in community-dwelling older adults. Different types of exercise interventions from randomized controlled trials have been shown to improve preferred gait speed.[14]

However, most studies were focused on clinical populations, and the heterogeneity of the interventions leads to inconsistent results on outcomes.[15] In particular, there is heterogeneity regarding the ways of defining and measuring gait ability in older adults, such as a performance-based test or usual gait speed.[16] Foot loading data (plantar pressure and force) can be used to analyze the effects of a treatment or an exercise intervention[15,17] since plantar pressure values present a consistent pattern in the elderly, and there is no age dependence of podobarometric data.[18,19] Nevertheless, the podobarometric effects of PA have rarely been investigated and reported in the literature. To the extent of our knowledge, the study developed by Monteiro et al[20] is the only study that aimed to investigate the effectiveness of a 12-month exercise program on podobarometric data in postmenopausal women and has proved that women who exercised have decreased loading of maximal peak pressures and absolute impulses. Furthermore, although periodization is an important method for training in athletes, there is still a lack of evidence of its use in untrained adults.[21]

Considering the importance of gait ability for the independence and quality of life of older adults, the aim of the study was to analyze the effects of a community-based periodized exercise intervention on the improvement of gait parameters and FF in an older adult group compared with a non-periodized program.

We hypothesized that a 6-month community-based periodized exercise intervention would be more effective than a non-periodized one for the maintenance or improvement of the gait and FF parameters of older participants.

Methods

Design

A quasi-experimental study was developed. The full protocol of the study is published elsewhere.[22] A multicomponent community-based exercise intervention named "More Active Ageing Program" (MAAP), organized in a group-based setting, was developed. The exercise group received a periodized intervention. The control group was committed to a non-periodized intervention. The intervention was carried out for 24 weeks, twice a week, each session spanning 50 minutes. We compared the MAAP (exercise group 1 = EG1) with other non-periodized program (NOPP) (exercise group 2 = EG2) for older adults, also described in Ramalho et al.[22]

The study was conducted in partnership with Sport Sciences School of Rio Maior of the Polytechnic Institute of Santarém and the research center CIPER of the Faculty of Human Kinetics of the University of Lisbon. This study received ethical approval from the Ethics Committee of the Faculty of Human Kinetics, University of Lisbon.

Setting

The intervention was implemented in six community centers, in five municipalities of West and Ribatejo regions of Portugal, allowing the recruitment of participants living in small towns and rural areas. The exercise program "MAAP" (EG1) was implemented in three of these centers. The other groups attended the exercise program "NOPP" (EG2) in the other three settings. Eligible individuals were invited to attend a formal in-person screening and then to participate in one of the community centers without any payment.

Participants

Participants were considered eligible for the study if they were aged ≥65 years, community-dwelling living, understand

Portuguese language, and agree to participate voluntarily in this study. The exclusion criteria were to have a neurologic condition (eg, dementia or Parkinson disease), a cardiovascular condition (eg, stroke), or other abnormality that would influence the ability to answer a questionnaire, inadequate proficiency in Portuguese language, to use a walking aid, presence of hip, knee, or ankle prosthesis, foot disorders, or incapacity of performing exercises in the standing position. Older male and female adults were recruited through advertisements posted within the local community.

Participants were randomly assigned to each exercise group (EG1 or EG2) taking into account the geographical proximity of their homes and intervention settings, that is, they were given the opportunity to choose between, at least, two of the available settings. The participants of both the groups were assessed at baseline and after 6 months of intervention. A maximal of 20 participants performing exercise at the same time were allowed due to practical, pedagogical, and methodologic issues related to the training.

Of a total of 40 participants recruited for the intervention, 20 were engaged in the EG1, and other 20 older adults were engaged in the EG2. Since they missed (or "because they have missed") the second assessment, five subjects were excluded from the analysis in EG1 (12.5% loss of follow-up) and seven in EG2 (17.5% loss of follow-up).

Fifteen participants of the EG1 (mean age of 68.0±5.9 years at baseline; 66.0±16.4 kg of body mass; 85% females) and 13 participants of the EG2 (mean age of 67.8±5.2 years at baseline; 72.1±10.3 kg of body mass; 85% females) were assessed. Figure 1 depicts the recruitment, randomization, and assessment processes.

The project manager explained the objectives of the study and answered all questions before asking the participant to consent the participation in the study. A written informed consent was obtained from all participants at the beginning of the intervention, before the allocation to the groups. All participants were instructed to maintain their normal lifestyle through the intervention.

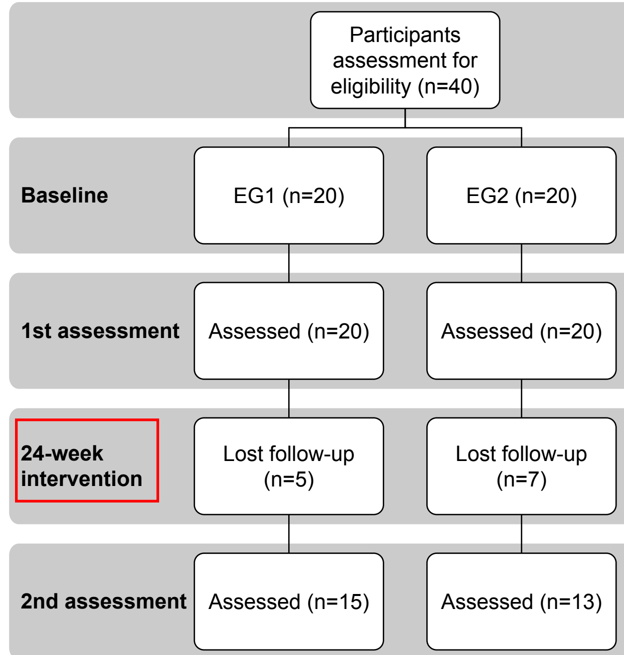

Figure 1 Flow diagram of the recruitment, randomization, and assessment processes.
Abbreviation: EG, exercise group.

Exercise intervention

All exercise sessions included in both the exercise programs were delivered by different graduated exercise specialists, blind to the intervention. Participants were instructed to wear comfortable sportswear and sports shoes during both the interventions.

EG1 was engaged in an exercise program MAAP, which was controlled, periodized, and organized, according to the structure presented in Ramalho et al.[22] The rational is also explained in the study protocol.[22] The MAAP was designed to focus specifically on the postural stability, balance, and strength in lower limbs, combined with aerobic exercise, at a level of intensity in accordance with the participants' functional capacities. The components of posture stability, balance, and strength training were based on group exercise and circuit training. The aerobic component was based on walking and mobility group exercise. During the first period of 12 weeks, more emphasis was given to the development of postural control and balance, and the second period of 12 weeks was more focused on strength and muscle resistance improvement in lower limbs. The exercise specialists responsible for NOPP (EG2) followed the same planning on all subgroup classes, in accordance with the recommendations provided by the American College of Sports Medicine (ACSM)[23] and Rose.[24] The NOPP program was designed to focus on balance, strength, and aerobic exercise, without any specific periodization. A more detailed description of this exercise program is also described in Ramalho et al.[22]

The participation of all subjects was controlled through attendance forms and session goal checklists. Participants with an attendance rate <75% of the sessions in each of the programs' mesocycles would be excluded from the analysis. However, all participants attended at least 95% of the sessions. The loss of follow-up refers to participants who missed one of the assessments, and for that reason, they were excluded from the analysis (Figure 1).

The independent variables of this study were the features (type, duration, frequency, intensity, and progression/periodization) of the exercise programs.

Testing procedures

All measurements were applied using standardized protocols and trained researchers.

Gait assessment

Gait parameters were obtained using a Novel emed-x system platform (Novel, Münich, Germany) with a high sensor resolution mode with a sensor resolution of 4 sensors/cm^2 and a frame rate of 100 Hz. Gait parameters were recorded as participants walked barefoot across a 10 m walkway placed on the floor, at self-determined velocity. The participants performed few trials before data collection, in order to be familiarized with the task. Five stances from each foot from each participant were collected and analyzed. Portable equipment was used to collect data in the same setting where the exercise interventions and the other assessments took place.

The primary outcome variables were the following gait parameters: 1) applied local force-maximum vertical ground reaction force (max force); 2) maximum applied local pressure (peak pressure); 3) maximum mean applied pressure (max mean pressure); 4) force–time integral (FTI) in an anatomical area; 5) PTI. For subsequent analysis of force and plantar pressure, each foot (right and left) was divided into six anatomical areas: "hindfoot," "midfoot," "medial forefoot," "hallux," "toes," and "lateral forefoot" (metatarsal heads), plus "total foot." The total foot and the six foot areas selected for analysis are depicted in Figure 2.

The Novel software was used for data analysis. Force data were normalized to the BW. This process allows better comparisons between participants since it eliminates differences in BW as a potential confounder during statistical analysis. Since a previous comparison showed no significant differences between right and left foot, the mean values of both feet were used in the subsequent statistical analysis.

FF assessment

FF tests included in the "Senior Fitness Tests" (SFT) battery[25] were administered by trained examiners after engaging in a training workshop, which previously demonstrated a high inter-observer agreement for all FF tests.[26] The tests "30 sec chair stand," "8 ft up&go," and "2-min walking" were used to assess lower limb strength, agility, and aerobic endurance, respectively. Both dynamic and static balance were evaluated through two tests each (FAB 1–4), included in the "Fullerton Advanced Balance Scale."[24] These FF parameters were the secondary variables of the study. All participants followed a familiarization session of 15 minutes (2 minutes for each test) 1 week before the baseline assessments.

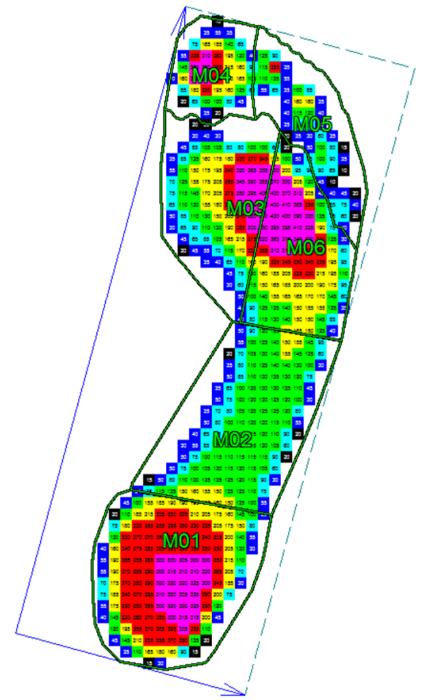

Figure 2 The six foot regions in analysis: M01 – hindfoot (heel); M02 – midfoot; M03 – medial forefoot; M04 – hallux; M05 – toes; M06 – lateral forefoot.

Demographics, health, and physical activity assessment

The characteristics of the participants included in the study were demographics, self-perception of health and falls prevalence, medication intake, PA levels, body mass, height, and body mass index (BMI).

Self-perception of health status and falls prevalence – defined as the experience of any falls during the period before assessments: previous 12 months at baseline and during the follow-up period – were assessed by a questionnaire designed and validated for Portuguese language and culture.[27]

PA profiles were also evaluated by a short version of "Yale Physical Activity Survey" (YPAS), validated for the Portuguese population,[28] which defines six distinct PA dimensions: 1) vigorous activity, 2) leisurely walking, 3) moving, 4) standing, and 5) sitting, and a PA total score, considering a typical week. Both questionnaires were administered by face-to-face interviews involving the same trained examiners. The procedures are described elsewhere.[26]

Height (m) and body mass (kg) were assessed using a stadiometer and calibrated scale SECA (model 220; SECA, Hamburg, Germany). BMI was calculated as kg/m^2.

Statistical analysis

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS version 23.0) to obtain descriptive statistics (mean and standard deviation) and to evaluate the effectiveness of the MAAP on the improvement of gait and FF parameters in the EG1, compared to the NOPP administered to the EG2. Data normality distribution was checked with the Shapiro–Wilk test. Paired *t*-tests (and the non-parametric Wilcoxon tests) were used to compare data at baseline and after 6 months of intervention. Independent sample *t*-tests (and the non-parametric Mann–Whitney *U* tests) were performed to compare the outcomes between the groups (EG1 versus EG2). Statistical significance was set at $p<0.05$.

Results

The characteristics of the participants, as well as the results of FF parameters (secondary variables) in both the groups, at baseline and after the exercise intervention, are summarized in Table 1.

Regarding both the exercise interventions, none of the participants reported any injury or complications in their feet during the intervention period and showed no signs of excessive fatigue or discomfort during the assessments.

There were no differences between groups, at baseline and after the intervention, regarding self-perception of health (3.5±0.4 score units), number of intake medications (2.5±1.3), and falls prevalence in the last year (0.2±0.1). There were no differences between groups regarding the participants' BW, BMI, and PA level, neither at baseline nor after the intervention, except for "moving score" which increased after the intervention.

Regarding the FF variables, there are no differences between groups at baseline. The results point to the maintenance of most FF parameters after the 24-week exercise intervention, except for the "30 sec chair-stand" test that increased in EG2 after intervention and in comparison with EG1.

The results of gait parameters (primary outcomes) in both the groups at baseline and after the exercise intervention are summarized in Tables 2–5.

At baseline, there were no significant differences between groups regarding the analyzed variables (Table 2). The significant changes between baseline and after the intervention in both the groups are depicted in Figures 3–7.

Regarding the potential effects of the MAAP, the following parameters showed a significant decrease after the intervention: maximal force in the hallux; maximal mean pressure in all foot, toes, and lateral forefoot; peak pressure in all foot

Table 1 Characteristics of the participants and functional fitness results in both the exercise groups, at baseline and after the 24-week exercise intervention

Factors	**Exercise group 1 (EG1) N=15**		**Exercise group 2 (EG2) N=13**		***p*<0.05**
	Baseline	**After intervention**	**Baseline**	**After intervention**	
	Mean ± SD	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**	
Body weight (N)	653.01±81.23	647.78±80.04	676.3±88.8	674.0±82.8	
Body mass index (kg/m²)	27.2±3.5	26.4±3.3	28.0±2.5	27.6±2.6	
Vigorous walking (score units)	5.3±12.0	9.7±12.6	15.4±16.2	9.6±9.6	
Walking (score units)	9.3±5.2	11.2±7.7	13.0±12.8	18.6±13.7	¤
Moving (score units)	10.5±3.2	11.2±2.4	12.8±1.4	13.1±1.5	¥
Standing (score units)	7.9±1.8	8.4±1.9	9.0±1.0	9.3±1.0	
Sitting (score units)	2.3±0.8	2.3±0.8	2.3±0.5	2.1±0.5	
YPAS total (score units)	51.3±12.6	42.7±16.5	52.4±17.8	52.6±15.4	
30 sec chair-stand (number of repetitions)	15.3±3.7	16.4±2.8	16.3±3.1	21.2±5.8	¥,§
8 ft up&go (score units)	5.5±1.2	5.0±0.7	4.8±0.8	5.1±0.8	
2-min walking (score units)	105.9±21.4	111.7±17.5	110.8±21.5	111.8±25.1	
FAB1 (score units)	4.00±0.0	4.0±0.0	4.0±0.0	4.0±0.0	
FAB2 (score units)	3.3±1.0	3.7±0.5	3.3±1.0	3.6±0.7	
FAB3 (score units)	3.2±1.2	3.3±1.2	3.3±1.0	3.3±0.8	
FAB4 (score units)	3.7±1.0	3.7±0.6	3.9±0.3	3.9±0.3	

Notes: ¥Significant differences between EG1 and EG2 after intervention; ¤significant differences between baseline and after intervention in EG1; §significant differences between baseline and after intervention in EG2. "30 sec chair-stand" (CS), lower limbs strength test; "8 foot up&go" (UP), agility test; "2-min walking", aerobic endurance test; FAB1 and FAB2, dynamic balance tests; FAB3 and FAB4, static balance tests.

Abbreviations: EG, exercise group; YPAS, Yale Physical Activity Survey.

Table 2 Comparisons of the results of gait parameters between exercise group 1 and exercise group 2, at baseline

Gait parameters	Exercise group 1 (N=15) Mean ± SD	Exercise group 2 (N=13) Mean ± SD	Significance (two-tailed)
All_FTI	56.0±3.8	57.7±9.2	0.905
All_PeakF	115.7±5.8	116.4±9.4	0.548
All_MeanP	222.7±56.6	203.6±36.1	0.456
All_PeakP	641.2±194.1	534.8±69.4	0.183
All_PTI	226.3±58.1	208.5±41.6	0.381
M01_FTI	16.5±2.6	15.2±2.6	0.215
M01_PeakF	71.1±9.1	67.5±10.6	0.342
M01_MeanP	100.9±28.5	86.8±13.9	0.236
M01_PeakP	327.2±111.6	293.1±59.8	0.614
M01_PTI	74.8±21.4	66.1±10.6	0.456
M02_FTI	5.5±3.4	5.7±2.9	0.846
M02_PeakF	19.9±9.4	21.7±9.0	0.624
M02_MeanP	47.2±12.6	49.8±14.3	0.627
M02_PeakP	135.1±31.5	146.9±27.8	0.319
M02_PTI	39.5±12.6	42.9±16.1	0.537
M03_FTI	29.3±4.1	31.0±4.7	0.335
M03_PeakF	95.8±8.3	91.3±5.4	0.114
M03_MeanP	217.4±60.1	186.5±34.9	0.256
M03_PeakP	615.5±211.4	487.6±72.4	0.152
M03_PTI	169.4±52.5	147.4±30.6	0.427
M04_FTI	3.2±1.357	3.9±1.3	0.148
M04_PeakF	16.4±6.7	16.8±4.8	0.844
M04_MeanP	91.3±40.7	116.2±39.8	0.123
M04_PeakP	348.1±144.0	366.4±89.8	0.706
M04_PTI	69.7±32.2	94.0±51.2	0.139
M05_FTI	1.6±0.6	2.0±1.3	0.792
M05_PeakF	7.7±2.9	8.4±4.1	0.599
M05_MeanP	56.4±19.1	62.8±35.0	0.648
M05_PeakP	182.8±56.6	193.5±97.2	0.724
M05_PTI	42.4±13.9	52.0±36.9	0.581
M06_FTI	14.0±3.1	15.3±3.6	0.352
M06_PeakF	44.6±9.6	44.9±7.0	0.932
M06_MeanP	187.1±51.3	158.5±24.4	0.300
M06_PeakP	493.1±152.8	404.1±43.6	0.126
M06_PTI	140.6±43.6	122.5±18.9	0.829

Abbreviations: FTI, force–time integral in an anatomical area; PTI, pressure–time integral; PeakF, applied local force – maximum vertical ground reaction force; PeakP, maximum applied local pressure; MeanP, maximum mean applied pressure; M01, hindfoot; M02, midfoot; M03, medial forefoot; M04, hallux; M05, toes; M06, lateral forefoot.

Table 3 Comparisons of results of gait parameters between baseline and after exercise intervention in exercise group 1

Gait parameters	Exercise group 1 (N=15) Mean ± SD	Exercise group 2 (N=13) Mean ± SD	Significance (two-tailed)
All_FTI	56.0±3.8	55.2±5.2	0.650
All_PeakF	115.7±5.8	114.0±6.0	0.394
All_MeanP	**222.7±56.6**	**211.1±47.0**	**0.041**
All_PeakP	**641.2±194.1**	**606.5±164.7**	**0.027**
All_PTI	226.3±58.1	216.1±46.7	0.256
M01_FTI	16.5±2.6	16.5±2.3	0.865
M01_PeakF	71.1±9.1	72.5±9.6	0.532
M01_MeanP	100.9±28.5	102.9±26.2	0.439
M01_PeakP	327.2±111.6	332.5±86.7	0.363
M01_PTI	74.8±21.4	75.6±16.4	0.532
M02_FTI	5.4±3.4	5.2±3.5	0.349
M02_PeakF	19.9±9.4	18.9±9.1	0.140
M02_MeanP	47.2±12.6	47.6±18.2	0.477
M02_PeakP	135.1±31.5	139.7±44.0	0.315
M02_PTI	39.5±12.6	40.2±17.6	0.609
M03_FTI	29.3±4.1	29.1±4.9	0.776
M03_PeakF	95.8±8.3	94.8±8.2	0.691
M03_MeanP	217.4±60.1	206.9±48.7	0.086
M03_PeakP	**615.5±211.4**	**581.7±177.5**	**0.019**
M03_PTI	169.4±52.5	159.1±46.9	0.075
M04_FTI	3.2±1.4	2.9±1.1	0.281
M04_PeakF	**16.4±6.7**	**15.3±6.7**	**0.017**
M04_MeanP	91.3±40.7	86.8±36.4	0.426
M04_PeakP	348.1±144.0	329.3±143.1	0.140
M04_PTI	69.7±32.2	65.8±28.7	0.406
M05_FTI	1.6±0.6	1.4±0.7	0.129
M05_PeakF	7.7±2.9	7.4±3.8	0.820
M05_MeanP	**56.4±19.1**	**49.1±21.0**	**0.036**
M05_PeakP	182.8±56.6	169.2±66.2	0.201
M05_PTI	**42.4±13.8**	**37.4±14.4**	**0.047**
M06_FTI	14.0±3.1	13.8±3.2	0.532
M06_PeakF	44.6±9.6	43.9±9.2	0.609
M06_MeanP	**187.1±51.3**	**176.4±41.5**	**0.027**
M06_PeakP	493.1±152.8	469.0±131.8	0.062
M06_PTI	**140.6±43.6**	**132.0±40.3**	**0.028**

Note: Significant differences in bold case.
Abbreviations: FTI, force–time integral in an anatomical area; PTI, pressure–time integral; PeakF, applied local force – maximum vertical ground reaction force; PeakP, maximum applied local pressure; MeanP, maximum mean applied pressure; M01, hindfoot; M02, midfoot; M03, medial forefoot; M04, hallux; M05, toes; M06, lateral forefoot.

and medial forefoot; and PTI in toes and lateral forefoot. There was no change in the remaining assessed parameters.

For NOPP, the following parameters showed a significant decrease after the intervention: FTI in all foot, midfoot, and medial forefoot; maximal mean pressure in toes and lateral forefoot; peak pressure in the medial forefoot; and PTI in all foot, toes, and lateral forefoot. There was no change in the remaining assessed parameters.

After the intervention, significant differences were observed between groups in the following parameters: EG1 showed higher values than EG2 in FTI and PTI in the hindfoot region (Table 5).

Discussion

The aim of the study was to analyze the effects of a 6-month community-based periodized exercise intervention on the

Table 4 Comparisons of results of gait parameters between baseline and after exercise intervention in exercise group 2

Gait parameters	Exercise group 1 (N=15)	Exercise group 2 (N=13)	Significance (two-tailed)
	Mean ± SD	Mean ± SD	
All_FTI	**57.7±9.2**	**52.0±5.7**	**0.015**
All_PeakF	116.4±9.4	116.4±9.9	0.937
All_MeanP	203.6±36.1	195.0±45.5	0.209
All_PeakP	534.8±69.4	530.3±110.8	0.814
All_PTI	**208.5±41.6**	**187.9±35.3**	**0.034**
M01_FTI	15.2±2.6	14.6±2.0	0.480
M01_PeakF	67.5±10.3	72.2±7.7	0.209
M01_MeanP	86.8±13.9	91.0±13.7	0.439
M01_PeakP	293.1±59.8	306.7±48.3	0.583
M01_PTI	66.1±10.6	63.8±11.7	0.583
M02_FTI	**5.7±2.9**	**4.7±2.2**	**0.019**
M02_PeakF	21.7±9.0	20.6±9.0	0.308
M02_MeanP	49.8±14.3	46.0±12.9	0.136
M02_PeakP	146.9±27.7	144.3±31.2	0.784
M02_PTI	**42.9±16.0**	**36.0±10.6**	**0.019**
M03_FTI	**31.0±4.7**	**27.4±4.1**	**0.019**
M03_PeakF	91.3±5.4	90.0±5.7	0.638
M03_MeanP	186.5±34.9	179.3±39.7	0.086
M03_PeakP	**487.6±72.4**	**467.7±102.6**	**0.019**
M03_PTI	147.4±30.6	128.7±34.4	0.075
M04_FTI	3.9±1.3	3.6±1.1	0.388
M04_PeakF	16.8±4.8	17.7±5.5	0.388
M04_MeanP	116.2±39.8	113.6±42.7	0.695
M04_PeakP	366.4±89.8	381.1±108.2	0.530
M04_PTI	94.0±51.2	80.3±30.3	0.406
M05_FTI	2.0±1.3	1.7±1.0	0.129
M05_PeakF	8.4±4.1	8.4±3.9	0.875
M05_MeanP	**62.8±35.0**	**62.4±29.6**	**0.036**
M05_PeakP	193.4±97.2	208.8±91.1	0.065
M05_PTI	52.0±36.9	44.6±20.5	0.209
M06_FTI	15.2±3.6	12.9±2.3	0.532
M06_PeakF	44.9±7.0	42.9±5.6	0.583
M06_MeanP	**158.5±24.4**	**153.2±19.9**	**0.027**
M06_PeakP	404.1±43.6	381.4±57.3	0.062
M06_PTI	**122.5±18.9**	**106.3±17.6**	**0.028**

Note: Significant differences in bold case.
Abbreviations: FTI, force–time integral in an anatomical area; PTI, pressure–time integral; PeakF, applied local force – maximum vertical ground reaction force; PeakP, maximum applied local pressure; MeanP, maximum mean applied pressure; M01, hindfoot; M02, midfoot; M03, medial forefoot; M04, hallux; M05, toes; M06, lateral forefoot.

Table 5 Comparisons of results of gait parameters results between exercise group 1 and exercise group 2, after exercise intervention

Gait parameters	Exercise group 1 (N=15)	Exercise group 2 (N=13)	Significance (two-tailed)
	Mean ± SD	Mean ± SD	
All_FTI	55.2±5.2	52.0±5.7	0.144
All_PeakF	114.0±6.0	116.5±9.9	0.432
All_MeanP	211.1±47.0	195.0±45.5	0.379
All_PeakP	606.5±164.7	530.3±110.8	0.182
All_PTI	216.1±46.7	187.9±35.3	0.096
M01_FTI	**16.5±2.3**	**14.6±2.0**	**0.030**
M01_PeakF	72.5±9.6	72.2±7.7	0.936
M01_MeanP	102.9±26.2	91.0±13.7	0.272
M01_PeakP	332.5±86.7	306.7±48.3	0.365
M01_PTI	**75.6±16.4**	**63.8±11.7**	**0.046**
M02_FTI	5.2±3.6	4.7±2.2	0.654
M02_PeakF	18.9±9.1	20.7±9.0	0.627
M02_MeanP	47.6±18.2	46.0±12.9	0.525
M02_PeakP	139.7±44.0	144.3±31.2	0.760
M02_PTI	40.2±17.6	36.0±10.6	0.922
M03_FTI	29.1±4.9	27.4±4.1	0.361
M03_PeakF	94.8±8.2	90.0±5.7	0.098
M03_MeanP	206.9±48.7	179.3±39.7	0.097
M03_PeakP	581.7±177.6	467.7±102.6	0.097
M03_PTI	159.1±46.9	128.7±34.4	0.079
M04_FTI	2.9±1.1	3.6±1.1	0.145
M04_PeakF	15.3±6.7	17.7±5.5	0.337
M04_MeanP	86.8±36.4	113.7±42.7	0.097
M04_PeakP	329.3±143.1	381.1±108.2	0.310
M04_PTI	65.8±28.7	80.3±30.3	0.262
M05_FTI	1.5±0.7	1.7±1.0	0.407
M05_PeakF	7.4±3.8	8.4±3.9	0.487
M05_MeanP	49.1±21.0	62.4±29.6	0.272
M05_PeakP	169.2±66.3	208.7±91.1	0.203
M05_PTI	37.4±14.4	44.6±20.5	0.289
M06_FTI	13.8±3.2	12.9±2.3	0.444
M06_ PeakF	43.9±9.2	43.0±5.6	0.758
M06_MeanP	176.4±41.5	153.2±19.9	0.172
M06_PeakP	469.0±131.8	381.4±57.3	0.097
M06_PTI	132.0±40.3	106.3±17.6	0.118

Note: Significant differences in bold case.
Abbreviations: FTI, force–time integral in an anatomical area; PTI, pressure–time integral; PeakF, applied local force – maximum vertical ground reaction force; PeakP, maximum applied local pressure; MeanP, maximum mean applied pressure; M01, hindfoot; M02, midfoot; M03, medial forefoot; M04, hallux; M05, toes; M06, lateral forefoot.

improvement of gait parameters and FF in an older adult group compared with a non-periodized program. We hypothesized that a periodized community program, in terms of its specific features (ie, type, intensity, frequency, duration, and progression), would be more effective in the improvement of gait and FF parameters within the older population, than a non-periodized exercise program.

The EG2 program increased significantly the strength in lower limbs and showed higher plantar pressure values (FTI and PTI in the hindfoot region). The MAAP was designed to focus specifically on the postural stability, balance, and strength in lower limbs, combined with aerobic exercise, which could justify the improvement in gait stability. On the other hand, the increased effectiveness related to EG2 should be analyzed with caution, because both the groups were involved in exercise programs with the same type of exercises, differing only on the progression of the

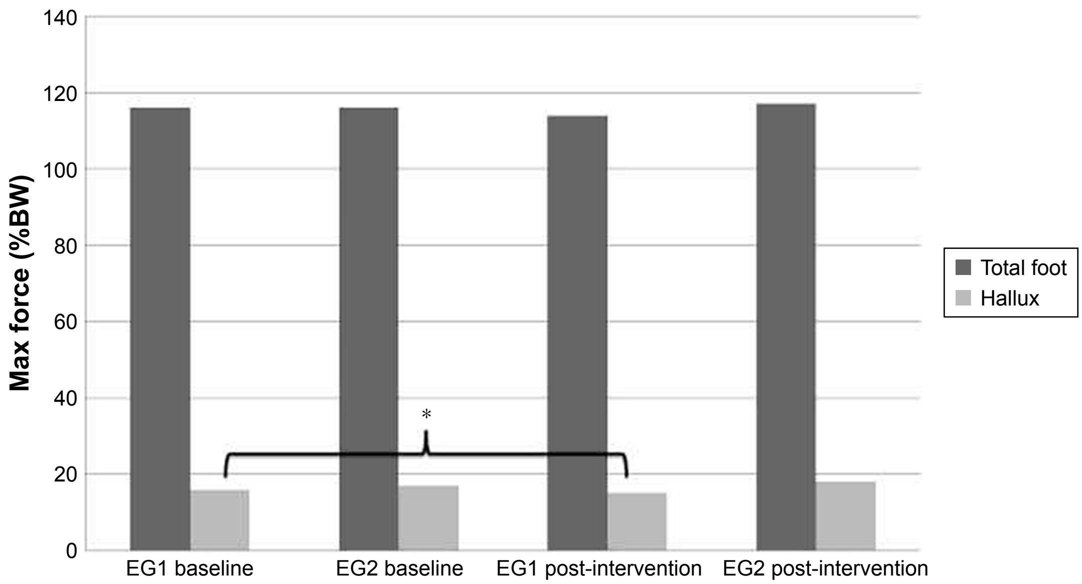

Figure 3 Significant changes between baseline and after intervention, in both the groups, regarding maximal force (*$p<0.05$).
Abbreviations: EG1, exercise group 1; EG2, exercise group 2.

sessions and in the focus on postural control (EG1). The lack of improvement in most of the FF parameters can be explained by the ceiling effect, mainly on the balance parameters. However, the motor skills developed in MAAP exercise intervention followed by EG2 led to an improved balance control, particularly by an increase in postural regulation as manifested in the observed decrease in plantar pressure. Moreover, the reduction of plantar pressure manifested in hindfoot means that the initial contact of the gait was done with greater movement control, which represents an important indicator of the impact on adverse outcomes, namely on the decrease of the risk of falling. On the other hand, both the elderly groups were quite fit at baseline, and exercise volume was not sufficient to promote a significant increase in overall FF in EG1, but only to improve fewer functional capacities and to maintain other in this group. The motor

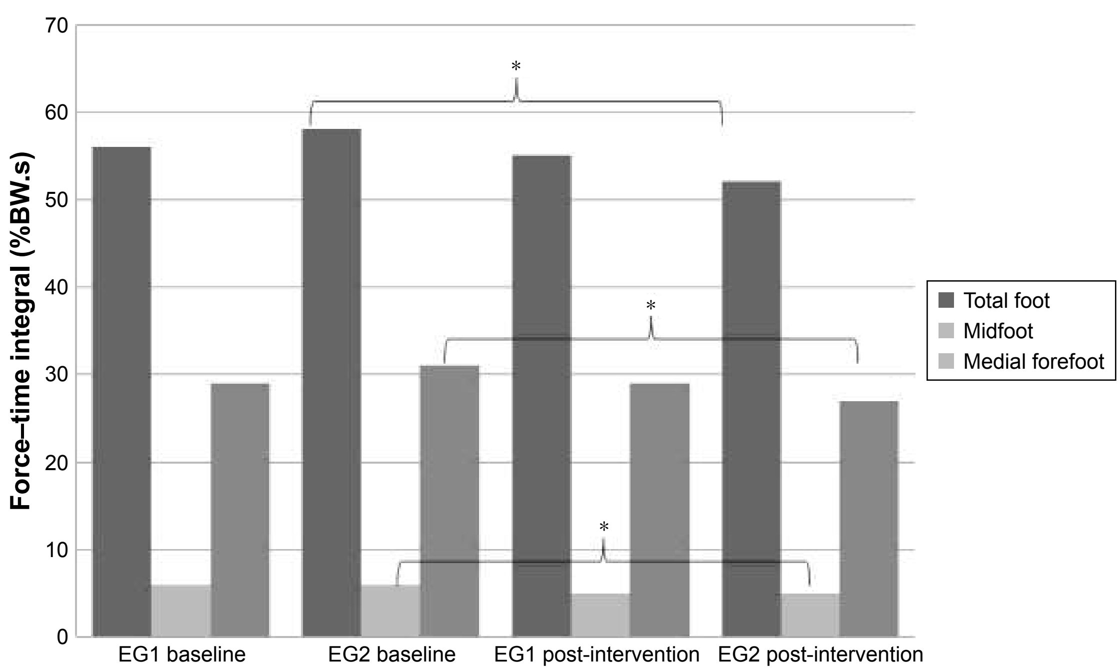

Figure 4 Significant changes between baseline and after intervention, in both the groups, regarding force–time integral (*$p<0.05$).
Abbreviations: EG1, exercise group 1; EG2, exercise group 2.

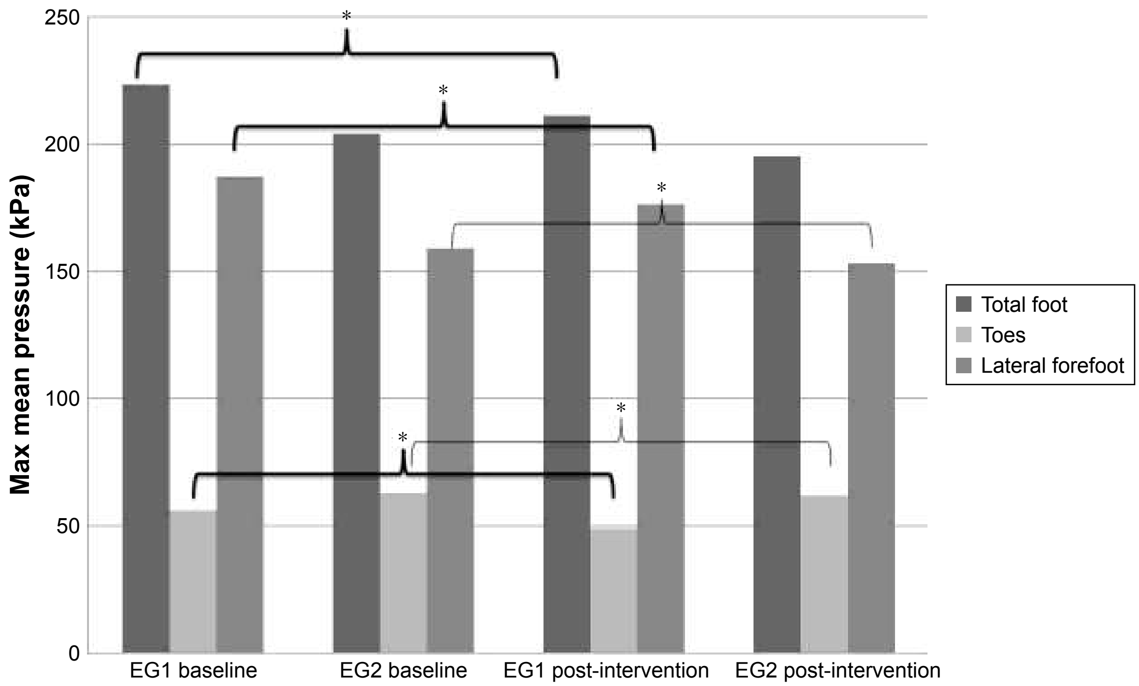

Figure 5 Significant changes between baseline and after intervention, in both the groups, regarding maximal mean pressure (*$p<0.05$).
Abbreviations: EG1, exercise group 1; EG2, exercise group 2.

skills developed in MAAP exercise intervention followed by EG2 led to an improved balance control, particularly by an increase in postural regulation as manifested in the observed decrease in plantar pressure. These results are quite similar to those obtained by Burton et al.[29] In this line, the ACSM issued what is considered as the gold standard of exercise prescription for healthy old adults.[23] However, a careful examination of this position stand suggests the number of

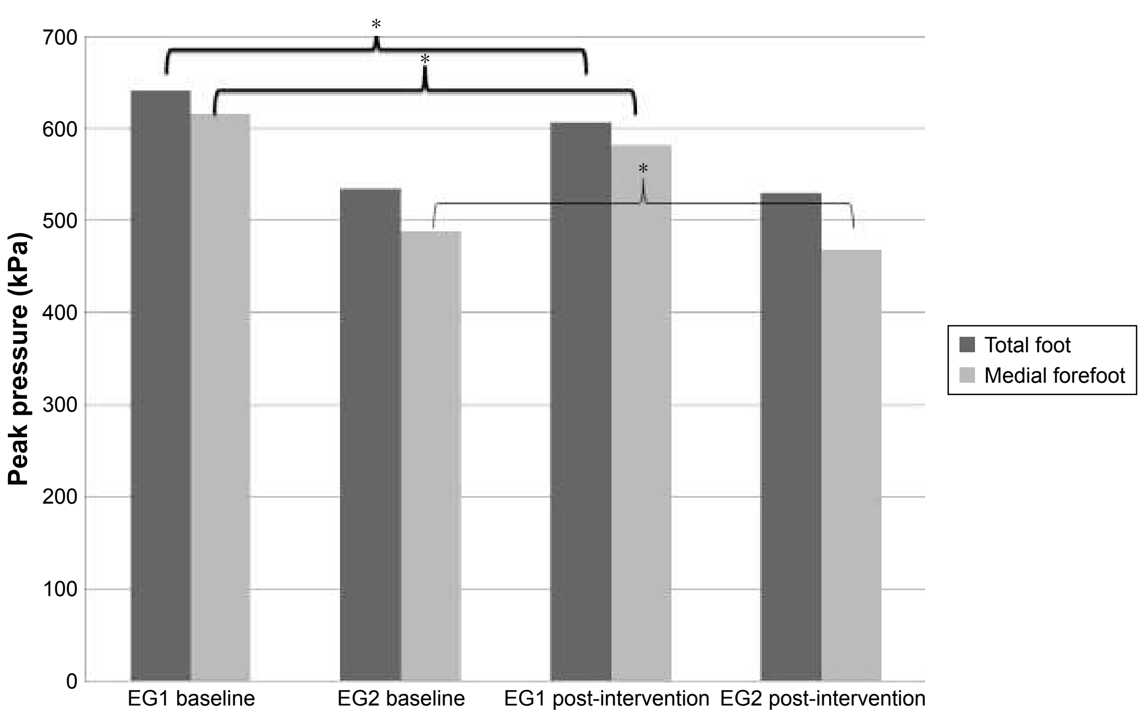

Figure 6 Significant changes between baseline and after intervention, in both the groups, regarding peak pressure (*$p<0.05$).
Abbreviations: EG1, exercise group 1; EG2, exercise group 2.

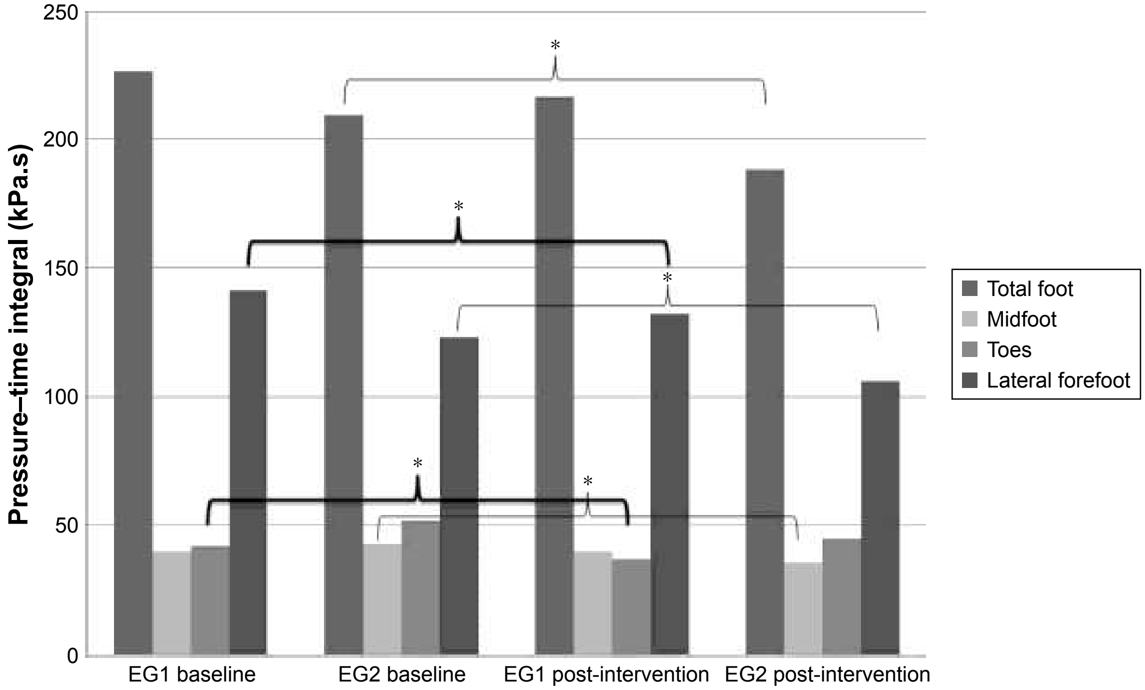

Figure 7 Significant changes between baseline and after intervention, in both the groups, regarding pressure–time integral (*$p<0.05$).
Abbreviations: EG1, exercise group 1; EG2, exercise group 2.

included training variables (eg, traditional variables such as training period, frequency, volume, intensity only),[30] and by focusing only on direct comparisons of exercise groups (eg, high vs low intensity), it seems weak to measure the effectiveness of exercise programs. Moreover, the absence of reference values about the minimum detectable difference in the various dimensions of FF does not allow us to consider the conditions about the existence or not of improvements in the groups. In this study, this is especially important, because both the exercise groups included active older adults, and the quantification of the dose–response relationships/answers are more difficult to achieve.

More research is needed with studies using larger sample sizes, and longer follow-up periods, to establish evidence-based recommendations. However, our results regarding the main outcomes are important, considering that higher plantar pressure values have been associated with a change in walking strategy and an increase in fall risk. Gait impairment has frequently been detected in frail patients, especially a reduction in gait speed.[3,31] However, there are other gait parameters such as the 10 spatiotemporal addressed by Ritt et al in a cross-sectional study.[31] Moreover, those parameters might most accurately predict 1-year mortality.[32]

We speculate that the long-term effectiveness of this type of exercise interventions will be established at the level of general mobility by means of adopting an active lifestyle, which can be translated into improved autonomy, independent living, and prevention of falls.[33] The risk of falling associated with movement patterns in which elderly patients present higher GRF values in heel-contact (initial contact) may explain a higher plantar pressure in the hindfoot zone (which decreased in EG2). The results showed that the exercise programs, both periodized and non-periodized issues and tailored to older adults, were proved to be effective in reducing the age-related decline regarding FF and improve gait parameters. In this line, the efficacy of the exercise programs on the reduction of risk of falling in the long term is promising.[14,33]

To our knowledge, this is the first study investigating the effect of exercise and its organization (periodized vs non-periodized program) on gait, based on peak forces and plantar pressures in independent community-dwelling older adults. Apart from this innovation, the major strength of this study was the ecological approach used, that is, the development and implementation of exercise interventions, combining the advantages of a community group program with the efficacy of controlled exercise and a progressive stimulus tailored to participant's FF level. The intervention was adapted to the typical community-based programs offered to the older population in rural areas and small towns. The programs were based on multiple component group exercise and showed great adherence, which in turn may contribute to compliance and long-term maintenance of older people.

Regarding the implications for practice, the present study has demonstrated that long-term periodized and non-periodized exercise programs tailored to older adults proved to be effective in reducing the age-related decline regarding FF and selected gait parameters. Both the exercise programs were safe, targeted to the physical fitness levels, and can be used by exercise professionals in prescribing community exercise programs, as well as by health professionals in promoting active aging and health among older adults. It is important to highlight the relevance of postural control exercises in exercise programs for elderly people, due to the positive repercussions that may have on the gait pattern, regardless the improvement of FF dimensions, leading to the prevention of falls in community-dwelling older adults.

Since an ecological approach was used, and as stated in the study protocol, the limitations of this study are related to the difficulties of randomization of the groups since older people were keener on participating in the program that provides a more convenient setting, either because it was not far from their homes or where were their friends. Moreover, the time-consuming events related to the assessment of different variables required extra time from the participants, and the loss of follow-up in this study was related to the second period of assessment. Future studies should have a larger sample size and a better randomized procedure to investigate the long-term effects of exercise training on gait loading parameters.

Further research should focus on increasing the number of participants and age intervals, allowing the training effects of MAAP program, between active and sedentary older adults, with differentiated functional capacity. The equipment and methodology used for gait analysis have progressed substantially in recent years. Thus, longitudinal studies are required to test which gait parameters, either kinetics or kinematics, are more sensitive to tailored exercise interventions.

Conclusion

Exercise programs tailored to older adults (periodized or non-periodized) are effective on mobility improvement and helps to maintain FF in elderly. An explanation for these effects in our study could be higher quality in the execution of exercises due to supervision. In fact, evaluation of the exercise diaries revealed similar mean stages of progression between groups. This implies that a higher rate of exertion and consequently a larger adaptation were achieved in both the experimental groups. The question remains as to why periodized program improved physical performance. It is possible that a higher dose needs to be applied in order to improve all functional parameters and thus a more effective improvement in gait.

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Author contributions

All authors contributed toward data analysis, drafting and revising the paper and agree to be accountable for all aspects of the work.

Disclosure

The authors report no conflicts of interest in this work.

References

1. American College of Sports Medicine; Chodzko-Zajko WJ, Proctor DN, Fiatarone Singh MA, et al. American College of Sports Medicine position stand. Exercise and physical activity for older adults. *Med Sci Sports Exerc*. 2009;41(7):1510–1530.
2. Menz HB. Biomechanics of the ageing foot and ankle: a mini-review. *Gerontology*. 2015;61(4):381–388.
3. Schwenk M, Howe C, Saleh A, et al. Frailty and technology: a systematic review of gait analysis in those with frailty. *Gerontology*. 2014;60(1):79–89.
4. Amemiya A, Noguchi H, Oe M, et al. Elevated plantar pressure in diabetic patients and its relationship with their gait features. *Gait Posture*. 2014;40(3):408–414.
5. O'Brien DL, Tyndyk M. Effect of arch type and body mass index on plantar pressure distribution during stance phase of gait. *Acta Bioeng Biomech*. 2014;16(2):131–135.
6. Mickle KJ, Munro BJ, Lord SR, Menz HB, Steele JR. Foot pain, plantar pressures, and falls in older people: a prospective study. *J Am Geriatr Soc*. 2010;58(10):1936–1940.
7. Fernando ME, Crowther RG, Lazzarini PA, et al. Plantar pressures are higher in cases with active diabetic foot ulcers compared to controls despite a longer stance phase duration. *BMC Endocr Disord*. 2016;16(1):51.
8. Sullivan J, Burns J, Adams R, Pappas E, Crosbie J. Plantar heel pain and foot loading during normal walking. *Gait Posture*. 2015;41(2):688–693.
9. Wang RY, Wang YL, Cheng FY, Chao YH, Chen CL, Yang YR. Effects of combined exercise on gait variability in community-dwelling older adults. *Age (Dordr)*. 2015;37(3):9780.
10. Paterson DH, Warburton DE. Physical activity and functional limitations in older adults: a systematic review related to Canada's Physical Activity Guidelines. *Int J Behav Nutr Phys Act*. 2010;11(7):38.
11. van der Bij AK, Laurant MG, Wensing M. Effectiveness of physical activity interventions for older adults: a review. *Am J Prev Med*. 2002;22(2):120–133.
12. Seco J, Abecia JC, Echevarría E, et al. A long-term physical activity training program increases strength and flexibility, and improves balance in older adults. *Rehabil Nurs*. 2013;38(1):37–47.
13. Wonneberger M, Schmidt S. Changes of gait parameters following long-term aerobic endurance exercise in mildly disabled MS patients: an exploratory study. *Eur J Phys Rehabil Med*. 2015;51(6):755–762.

14. van Abbema R, de Greef M, Crajé C, Krijnen W, Hobbelen H, van der Schans C. What type, or combination of exercise can improve preferred gait speed in older adults? A meta-analysis. *BMC Geriatrics*. 2015; 15(1):72.
15. Chen MS, Lin TC, Jiang BC. Aerobic and resistance exercise training program intervention for enhancing gait function in elderly and chronically ill Taiwanese patients. *Public Health*. 2015;129(8): 1114–1124.
16. Chung MJ, Wang MJ. Gender and walking speed effects on plantar pressure distribution for adults aged 20–60 years. *Ergonomics*. 2012; 55(2):194–200.
17. Kim SG, Park JH. The effects of dual-task gait training on foot pressure in elderly women. *J Phys Ther Sci*. 2015;27(1):143–144.
18. Franco PS, Silva CB, Rocha ES, Carpes FP. Variability and repeatability analysis of plantar pressure during gait in older people. *Rev Bras Reumatol*. 2015;55(5):427–433.
19. Lalande X, Vie B, Weber JP, Jammes Y. Normal values of pressures and foot areas measured in the static condition. *J Am Podiatr Med Assoc*. 2016;106(4):265–272.
20. Monteiro MA, Gabriel RE, Neves E, et al. Exercise effects in plantar pressure of postmenopausal women. *Menopause*. 2010;17(5):1017–1025.
21. Strohacker K, Fazzino D, Breslin WL, Xu X. The use of periodization in exercise prescriptions for inactive adults: a systematic review. *Prev Med Rep*. 2015;2:385–396.
22. Ramalho F, Carnide F, Santos-Rocha R, et al. Community-based exercise intervention for gait and functional fitness improvement in an older population: study protocol. *J Aging Phys Act*. 2017;25(1):84–93.
23. American College of Sports Medicine. *ACSM's Guidelines for Exercise Testing and Exercise Prescription*. 10th ed. Philadelphia, PA: Wolters Kluwer/Lippincott, Williams and Wilkins; 2017.
24. Rose DJ. *Fallproof!: A Comprehensive Balance and Mobility Training Program*. 2nd ed. Champaign, IL: Human Kinetics; 2015.
25. Rikli RE, Jones CJ. *Senior Fitness Test Manual*. 2nd ed. Champaign, IL: Human Kinetics; 2013.
26. Moniz-Pereira V, Carnide F, Machado M, André HI, Veloso AP. Falls in Portuguese older people: procedures and preliminary results of the study Biomechanics of Locomotion in the Elderly. *Acta Reumatol Port*. 2012;37:324–332.
27. Valente S. Validação de um questionário de saúde e identificação de factores de risco de quedas para a população idosa portuguesa [Validation of a health questionnaire and identification of fall risk factors among the Portuguese older population] [master's thesis]. Faculdade de Motricidade Humana – Universidade Técnica de Lisboa, Cruz-Quebrada; 2012.
28. Machado M, Tavares C, Moniz-Pereira V, André HI, Ramalho F, Veloso AP. Validation of YPAS-PT – The Yale Physical Activity Survey for Portuguese Older People. *Sci J Public Health*. 2016;4(1):72–80.
29. Burton E, Cavalheri V, Adams R, et al. Effectiveness of exercise programs to reduce falls in older people with dementia living in the community: a systematic review and meta-analysis. *Clin Interv Aging*. 2015; 10:421–434.
30. Raymond MJ, Bramley-Tzerefos RE, Jeffs KJ, Winter A, Holland AE. Systematic review of high-intensity progressive resistance strength training of the lower limb compared with other intensities of strength training in older adults. *Arch Phys Med Rehabil*. 2013;94(8): 1458–1472.
31. Ritt M, Schülein S, Lubrich H, Bollheimer LC, Sieber CC, Gassmann K-G. High-technology based gait assessment in frail people: associations between spatio-temporal and three-dimensional gait characteristics with frailty status across four different frailty measures. *J Nutr Health Aging*. 2017;21(3):346–353.
32. Ritt M, Ritt JI, Sieber CC, Gaßmann KG. Comparing the predictive accuracy of frailty, comorbidity, and disability for mortality: a 1-year follow-up in patients hospitalized in geriatric wards. *Clin Interv Aging*. 2017;12:293–304.
33. Gillespie LD, Robertson MC, Gillespie WJ, et al. Interventions for preventing falls in older people living in the community. *Cochrane Database Syst Rev*. 2012;9:CD007146.

- Linhas Orientadoras
- Planos de Sessão
- Checklists – Critérios de Êxito

Nota Introdutória

O presente documento faz parte da formação dos profissionais de exercício físico responsáveis por a implementação do programa “Envelhecimento Mais Ativo”, um programa de âmbito comunitário, dirigido à população idosa, com mais de 65 anos, funcionalmente independentes. O protocolo da intervenção foi definido por Ramalho F, Carnide F, Santos-Rocha R, André HI, Moniz-Pereira V, Machado M, Veloso AP, no artigo Community-Based Exercise Intervention for Gait and Functional Fitness Improvement in an Older Population: Study Protocol. J Aging Phys Act. 2017 Jan;25(1):84-93. Epub 2016 Sep 6 PubMed doi: 10.1123/japa.2015-0290.

Objetivos do Programa

O programa “Envelhecimento Mais Ativo” foi concebido com foco no controlo postural, equilíbrio e força dos membros inferiores e combinado com exercícios de características cardiovasculares, com intensidade ajustada ao nível funcional dos participantes.

Com uma duração de 36 semanas (9 meses), o programa divide-se em três fases:

- Fase I (primeiro ciclo de 12 semanas – outubro-dezembro) - caracterizada pelo desenvolvimento de controlo postural e equilíbrio estático e dinâmico;
- Fase II (13 a 24 semanas – janeiro - março) focada no aumento da força e resistência musculares dos membros inferiores;
- Fase III (25 a 36 semanas – abril-junho) marcada pelo desenvolvimento das componentes de condicionamento físico de maneira mais autónoma.

Foi definida uma frequência semanal de 2 sessões, com uma duração de 50m, orientadas por técnicos de exercícios físico que receberam um treino específico na metodologia do programa. De forma a complementar a formação dos profissionais, a formação presencial foi complementada por o acesso a conjunto de vídeos tutoriais que abordam as estratégias de progressão e de ensino, contribuindo para a implementação segura do programa. O link de acesso aos tutoriais é o seguinte:

https://www.youtube.com/playlist?list=PLZpu4KE37d7vHNrzIHIvWVVnhCuYxJOgj

Foi definido um planeamento de treino, ajustado aos diferentes níveis de condição física dos idosos e possível de ser aplicado em contexto comunitário, com reduzidos recursos materiais. As componentes controlo postural, equilíbrio e força foram desenvolvidos em sessões de dois tipos: grupo e circuito. A componente aeróbia foi associada a variações da marcha, mobilidade e equilíbrio dinâmico.

Mesociclos – Planos de sessão – Checklist de critérios de êxito

Para a implementação do programa, definidos os seguintes documentos:

1. Mesociclos _ Planos de sessão

   Foram considerados "mesociclos" períodos consecutivos de 4 semanas de treino. Para cada mesociclo foi elaborado um "Plano de Sessão" onde foram definidos os exercícios e aplicar, número de repetições e séries. Para o controlo do nível de intensidade, foi utilizada a escala subjetiva de perceção do esforço adaptada ao treino de força: Percived Exertion Scale for resistence Exercise – OMNIRES e Escala de Borg modificada para o treino aeróbio (Borg, 2000; Robertson et al., 2003). Considerando as diferentes fases do programa forma definidos os seguintes mesociclos para as 36 semanas de intervenção. Foram definidos os seguintes mesociclos:

   - Fase 1 – mesociclo 1 – outubro; mesociclo 2 – novembro; mesociclo 3 -dezembro.
   - Fase 2 – mesosciclo 1 – janeiro - o plano de sessão deste mesociclo manteve-se igual ao do mês de dezembro, prevenindo a possibilidade de destreino durante a interrupção do natal; mesociclos 2 e 3 – fevereiro e março – foi mantido o mesmo plano de sessão por o mesmo motivo do mês anterior (interrupção da Páscoa).
   - Fase 3 – mesociclo 1 – abril; mesociclo 2 – maio; mesociclo 3 – junho

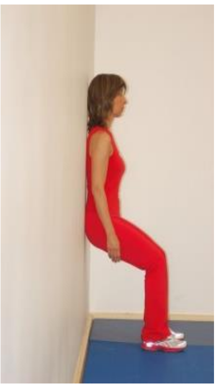
2. Checklist de critérios de êxito

   Para que ser possível avaliar o sucesso dos alunos em cada um dos exercícios propostos nos diferentes mesociclos do programa, foram criadas grelhas de observação que permitem identificar se foram atingidos os critérios de êxito. Para cada exercício, deverá ser indicado o número de alunos (% média aproximada) que cumpre cada um dos critérios definidos. Os técnicos de exercícios deverão utilizar a seguinte classificação: 1. Não conseguem atingir o critério de êxito; 2. Conseguem atingir o critério de êxito, mas com alguma dificuldade; 3. Conseguem atingir facilmente o critério de êxito.

Período 1 – mesociclo 1

Período 1 – mesociclo 1

Objetivos/Estratégias de Intervenção: Controlar alinhamento postural nas seguintes dimensões:
• Consciencialização os apoios e sua relação com os restantes segmentos corporais, em diferentes posições: bípede, 4 apoios, deitada a sentada • Exploração de diferentes técnicas respiratórias. • Ativação da “unidade interna” ou “core” (Diafragma, Transverso abdominal, Oblíquo interno, Multifidus, Pavimento Pélvico) • Alinhamento e estabilidade das cinturas pélvica (CP) e escapular (CE), através: 1. Controlo da mobilidade da coluna nas diferentes posições. 2. Controlo da estabilidade da coluna e cinturas (pélvica e escapular) durante a execução de movimentos dos membros Inferiores (MI) e membros superiores (MS).
Critérios de êxito gerais:
No final deste mesosciclo o aluno deverá ser capaz de: 1. Identificar a distribuição do peso corporal sobre os apoios de forma autónoma em qualquer posição 2. Identificar e executar os diferentes padrões respiratórios a partir da instrução verbal do professor 3. Conseguir mobilizar a coluna em todas as direcções mantendo a posição neutra da bacia e MI 4. Activar o “core”, utilizando a respiração torácica, e manter posição neutra da coluna e cinturas, enquanto realiza movimentos dos MI e MS nas diferentes posições. 5. Transitar, em segurança, da posição bípede para a de 4 apoios, desta para a posição deitada e voltar à posição bípede.
Orientações gerais:
1. As opções de execução deverão respeitar o nível de condição física do participantes e/ou disponibilidade de material 2. As progressões dos exercícios poderão ser alteradas pelo professor; no entanto, a ordem de execução deverá de ser mantida.

FASE INICIAL – 10-15’					
Controlo Postural – posição bípede					
Exercícios		**Imagens/ Instrução**	**Critérios de êxito**	**séries**	**Reps / Veloc. Exec.**
	1. Identificação da base de apoio;	**Pés**: Balançar peso sobre os pés em todas as direcções como um “sempre-em-pé”	1. Utilizar a respiração torácica na execução da maioria dos exercícios 2. Adoptar o alinhamento neutro de forma autónoma, sem qualquer apoio externo (ex: parede) enquanto realiza movimentos dos MI e MS 3. Realizar movimentos dos MI e MS com menor base de apoio (sem parede ou outro apoio) 4. Conseguir mobilizar a coluna em todas as direcções mantendo a posição neutra da bacia e MI	1	6-8 seguindo o ritmo respiratório individual
	2. Identificação da posição de cada segmento corporal em relação à base de apoio	**Joelhos:** flexão/extensão, adução/abdução “Afasta-junta” **Bacia:** retroversão/anteversão, “Salsa”, “Ponteiros do Relógio” **Omoplatas:** elevação/depressão; adução/abdução; rotação **Cabeça:** “Imagine um boneco que só mexe a cabeça”			
	3. Respiração:	**Resp. Abdominal ou Diafragmática:** “Encha a barriga como se fosse um grávida”;“Taça cheia de água”; “soprar as velas dos 90 anos” **Rep. Torácica ou lateral:** “Balão”ou “Fole” - as costelas se enchem como de ar, para os lados e para trás, sem elevar os ombros e sem mover a bacia” **Resp. Superficial ou superior:** “fungar”, “gargalhar”			
	4. Activação da Unidade Interna: Pavimento Pélvico, Transverso, Oblíquos, Multifidus, Diafragma “Ex..Kegle” “Finger tip Abdominals”	**Exercícios de Kegle** “Conter a urina” sem activar abdominais e/ou glúteos. **“Finger tip Abdominals”** “Durante a expiração profunda, sinta, nas pontas dos dedos, o Tranverso aproximar cristas ilíacas, como um elástico, sem mover a bacia ou coluna lombar”			

	5. Mobilização da coluna com estabilidade da bacia	Com e sem apoio da parede **Flexão lateral** "Árvore que se agita ao vento"; "Crescer": **Flexão Anterior/Extensão** "Imagine a coluna com um colar de pérolas que se dobram entre si e são capazes de retomar a posição inicial" **Rotação** Imagine que é toureiro que manipula a capa: "Olé"!			
	6. Manter alinhamento neutro enquanto se executam movimentos dos MS e MI	**Membros Superiores:** Flexão dos braços – "levante uma caixa" Rotação externa - "Abra a cortina" Extensão – "Empurre a parede" (mãos ou cotovelos". **Membros inferiores:** "Deslize na parede, peso distribuído sobre os pés"; "Não se sente na cadeira nem se ajoelhe"; "Elevar calcanhares" (joelho estendidos); "Bater os pés no chão" (joelhos flectidos). **Integração** braços/pernas em simultâneo.			

Orientações gerais:

1. A selecção dos exercícios poderá ser alterada pelo professor, de acordo com as opções sugeridas no capítulo "Exercícios"; no entanto, a ordem de execução terá de ser mantida
2. Nos movimentos dos membros superiores é necessário respeitar a seguinte ordem:
   - Amplitude progressiva dos movimentos de acordo com a capacidade funcional e/ou limitações osteoarticulares do participante.
   - Começar por ações no plano sagital (flexão – MS na direcção das orelhas) e depois planos frontal (aberturas) ou circunduções (Círculos).
   - Enfatizar a estabilização das omoplatas durante a execução destes movimentos.

<table>
<tr><th colspan="6">FASE PRINCIPAL</th></tr>
<tr><th colspan="6">Controlo Postural - Posição de 4 apoios – 5’</th></tr>
<tr><th colspan="2">Exercícios</th><th>Imagens/ Instrução</th><th>Critérios de êxito</th><th>séries</th><th>Reps / Veloc. Exec.</th></tr>
<tr>
<td rowspan="4">



</td>
<td>1. Identificar a base de apoio – mãos ou antebraços/joelhos</td>
<td>“Imagine que as mãos (ou antebraços) e joelhos estão sobre os vértices de uma caixa e desloque o peso do corpo sobre os 4 cantos da mesma”.</td>
<td rowspan="4">1. Mobilizar a coluna, e cinturas, e voltar à posição neutra, equilibrando um bastão nas costas, sem modificar a distribuição do peso nos apoios;
2. Realizar a respiração abdominal e torácica enquanto equilibra o bastão nas costas;
3. Manter posição neutra (coluna, cinturas) enquanto realiza extensão alternada dos MI e MS</td>
<td rowspan="4">1</td>
<td rowspan="4">6 e 8 Reps seguindo o ritmo respiratório individual</td>
</tr>
<tr>
<td>2. Identificar a posição neutra das cinturas escapular e pélvica</td>
<td>M. Inferiores: coxas á largura da bacia, calcanhares paralelos e dirigidos para o tecto, em linha com o joelho.
Bacia: retroversão/anteversão, “Salsa”, “Ponteiros do Relógio”.
Omoplatas: elevação/depressão; adução/abdução.
Cabeça: “Imagine um boneco que só mexe a cabeça”</td>
</tr>
<tr>
<td>3. Respiração, activação do “core e mobilidade da coluna/bacia:

“Grávida”
“Gato-Camelo”
“Tampo de Mesa”</td>
<td>a)Respiração Abdominal: Inspire formando uma barriga de “Grávida”.
b) Respiração Torácica e mobilidade da coluna - “gato /camelo” – inspire na posição de extensão e expire enquanto flecte a coluna (“Gato”). Inspire na posição do “Gato” e expire durante a extensão da coluna e bacia, nunca desactivando o transverso (“Camelo”).
c).“Imagine as suas costas como um tampo de mesa onde equilibra um copo e realiza a respiração torácica e activa o core”.</td>
</tr>
<tr>
<td>4. “Super-homem modificado”: Extensão do MI ou MS mantendo alinhamento das cinturas e bacia</td>
<td>a)“Coice”: deslize o pé no solo enquanto expira
b) “empurrar a água na piscina” – estenda o braço a trás, mantendo-o junto às costelas.</td>
</tr>
<tr><td colspan="6">Orientações gerais:
1. Ordem de progressão das opções de execução: parede (mãos ou antebraços e pés); cadeira ou step (mãos ou antebraços e joelhos); solo (mãos e joelhos).</td></tr>
</table>

FASE PRINCIPAL					
Controlo Postural - Posição decúbito dorsal (DD) – 10'					
Exercícios		**Imagens/ instrução**	**Critérios de êxito**	**séries**	**Reps / Veloc. Exec.**
	1. Sequência de consciencialização dos apoios indicada para a posição bípede.	"Sentir" o pé, coxa/joelho, apoio da bacia, omoplatas/membros superiores, cervical, nuca.			
	2. Treino das respirações: a) abdominal; b) torácica, e c) superficial.	a) "grávida" ou "fole"; b) "Balão" sentir banda elástica ou toalha a mover; c)"Fungar" ou "Gargalhar".			
	3. "Activação do "core" e alinhamento neutro "Ex. Kegle" "Finger tip Abdominals".	"**Exercícios de Kegle** "Conter a urina" sem activar abdominais e/ou glúteos. **"Finger tip Abdominals"** "Durante a expiração profunda, sinta, nas pontas dos dedos, o Tranverso aproximar cristas ilíacas, como um elástico, sem mover a bacia ou coluna lombar".		1	6-8 Reps de seguindo o ritmo respiratório individual
	4. "Mobilidade e estabilidade da região lombo pélvica e força dos MIs "Ponte de ombros".	a)Mobilidade lombo-pélvica e força dos membros inferiores: "Imagine que está deitado, a tentar fechar o fecho e a apertar o cinto de umas calças muito justas".	Mobilizar a coluna e bacia sem alterar a posição da cintura escapular /nuca e voltar à posição neutra de forma controlada	2	6-8 reps de seguindo o ritmo respiratório individual.
	5. "Manter" a posição de ponte.	A partir da 5ª sessão introduzir: b) Estabilidade Lombo-pélvica, na posição de "Ponte""imagine que o seu corpo é uma rampa de lançamento ".	Manter a estabilidade lombo-pélvica na posição de maior extensão	2	Manter posição estática 2-4 ciclos respiratórios (respiração Torácica) por 6-8 reps

	6. “Rotação de Bacia”.	Através da contracção dos oblíquos, rodar bacia, mantendo os joelhos unidos, mantendo omoplatas e braços no lugar”	Manter omoplatas e MS estáveis enquanto realiza rotação da bacia e MI e ser capaz de regressar à posição inicial.	1	6 e 8 Reps de acordo com o ritmo respiratório individual
	7. Deslizar 1 pé no solo e estender o MI.	“imagine que o calcanhar empurra a parede.			
	8. Mesmo movimento com braços elevados.				
	9. “Toe taps” modificado - inicio no solo.	“Marcha deitada”: flexão/extensão alternada da coxa, a partir do solo, mantendo bacia cinturas e coluna neutras.	Manter posição neutra da coluna cintura escapular e pélvica, enquanto realiza o movimento sem o apoio dos braços.		
	10. Mesmo movimento com braços elevados.				

Orientações gerais:

1. A posição da nuca deve ser ajustada às limitações posturais do participante, recorrendo a toalha ou a almofada. A testa e o queixo deverão estar no mesmo plano evitando hiperextensão ou flexão da cervical.
2. As opções de execução deverão respeitar o nível de condição física do participantes e/ou disponibilidade de material.
3. A “ponte de ombros” é um dos exercícios “chave” para aumento da força, equilíbrio do MI e estabilidade lombo-pélvica, devendo o estímulo imposto ser aumentado ao longo dos mesociclos seguintes.
4. A selecção dos exercícios poderá ser alterada por o professor, no entanto, a ordem de execução terá de ser mantida.

<table>
<tr><th colspan="6">FASE PRINCIPAL</th></tr>
<tr><th colspan="6">Controlo Postural - Posição decúbito lateral (DL) – 5’</th></tr>
<tr><th colspan="2">Exercícios</th><th>Imagens/ instrução</th><th>Critérios de êxito</th><th>séries</th><th>Reps / Veloc. Exec.</th></tr>
<tr><td rowspan="3"></td><td>1. Identificação do alinhamento neutro:
• desequilíbrio da bacia (anterior/posterior);
• Costelas (distância para o solo);
• ombro e omoplata (elevação/depressão, circundução).</td><td>“Imagine que a sua nuca, omoplatas e sacro estão encostados a uma parede, com as coxas e joelhos flectidos e pés virados para trás, na mesma linha da bacia e coluna. Desloque o peso do corpo, para a frente e para trás. Mantenha o “cinto”apertado (abdominais e multifidus) para manter a cintura afastada do colchão.”</td><td>Encontrar a posição neutra de forma autónoma, mantendo os MI flectidos (maior base de apoio).</td><td rowspan="3">1</td><td rowspan="3">6 e 8 Reps de acordo com o ritmo respiratório individual.</td></tr>
<tr><td>2. “Ostra” (rotação externa. da coxa)</td><td>“Afaste as coxas como se fossem os 2 lados de uma ‘ostra”.</td><td rowspan="2">Manter posição neutra, com a mão livre apoiada no solo, enquanto movimenta o MI livre, em 8 repetições consecutivas</td></tr>
<tr><td>3. “Círculos” com o MI livre – rotação interna e externa</td><td>“Com o MI livre em extensão, e pé flectido, desenhe um ‘O” com o pé no ar” – Executar nos 2 sentidos</td></tr>
<tr><td colspan="6">Orientações gerais:
1. Começar para um dos lados e alterne com posição deitada ou 4 apoios.
2. De forma a garantir que a região cervical fica em alinhamento com os restantes segmentos da coluna, a cabeça deverá estar apoiada sobre uma toalha dobrada entre a orelha e o membro superior em contacto com o solo (flectido na direcção da cabeça).
3. Em indivíduos com patologias do ombro, o membro superior em contacto com o solo deverá estar em flexão anterior (perpendicular ao tronco), ficando a cabeça apoiada numa toalha ou almofada
4. As opções de execução deverão respeitar o nível de condição física dos participantes e/ou disponibilidade de material.
5. A selecção dos exercícios poderá ser alterada pelo professor; no entanto, a ordem de execução terá de ser mantida.</td></tr>
</table>

FASE PRINCIPAL					
Controlo Postural - Posição - Posição 4 apoios – 5’					
Exercícios		**Imagens/ instrução**	**Critérios de êxito**	**séries**	**Reps / Veloc. Exec.**
	1. Sequência de consciencialização dos apoios e do alinhamento neutro anteriormente executados.	Ver imagens indicadas anteriormente para esta posição.	Encontrar a posição neutra de forma autónoma, com mãos ou antebraços em apoio na cadeira ou solo.	1	6 a 8 Reps seguindo o ritmo respiratório individual
 	2. “Super-Homem modificado Extensão do MI e manter a posição.	“Coice”, “Empurrar a parede da sala”.	Manter posição neutra, durante 2 ciclos respiratórios, equilibrando um bastão ou outro objecto nas costas.		
	3. Super-Homem “modificado” Extensão e Flexão do MS sem modificar o alinhamento da coluna e cinturas.	a)“Empurrar a água na piscina” b)Levantar areia do chão com a palma da mão.	Manter posição neutra enquanto movimenta MI e MS.		
 	4. Preparação para “prancha” de braços - elevar joelhos do solo	“empurrar” o solo, elevando os joelhos e mantendo o apoio nos antebraços e Pés.	Na fase de transição para posição bípede, mantém postura neutra durante 2 ciclos respiratórios, enquanto eleva do solo os joelhos (apoio de mãos e pés.		

Orientações gerais:

1. As opções de execução deverão respeitar o nível de condição física do participantes e/ou disponibilidade de material.
2. A selecção dos exercícios poderá ser alterada pelo professor; no entanto, a ordem de execução terá de ser mantida.

<table>
<tr><th colspan="5">FASE FINAL – 10’</th></tr>
<tr><th colspan="5">Posição bípede</th></tr>
<tr><th colspan="2">Exercícios</th><th>Critérios de êxito</th><th>séries</th><th>Reps / Veloc. Exec.</th></tr>
<tr><td rowspan="2">Transferências de apoio</td><td>1. Transferências de apoio simples com joelhos relaxados nas bases: “Afastada”, “T afastado” e “Unida”.</td><td rowspan="2">Realizar com sucesso as transferências de peso com os joelhos relaxados, mantendo a estabilidade nos apoios e a postura neutra da coluna na posição bípede.</td><td rowspan="2">1 cada lado</td><td rowspan="2">2 reps de cada movimento completo a uma cadência de 4 T cada fase</td></tr>
<tr><td>2. Transferências de apoio com mudança de base entre as posições: “Base Afastada” - “Base Unida” e caminho inverso.</td></tr>
<tr><td rowspan="4">Cardio</td><td>1. Balanços simples com movimentos de braços.</td><td rowspan="4">Realizar os movimentos “a tempo”, durante 5 min contínuos, na cadência e intensidade recomendadas.</td><td rowspan="4">-</td><td rowspan="4">• Velocidade da música utilizada: cadência entre 124-128 BPM‘s
• intensidade 4-5 na EPSE</td></tr>
<tr><td>2. Balanços laterais com movimentos de braços.</td></tr>
<tr><td>3. Combinação dos balanços com rotação do tronco.</td></tr>
<tr><td>4. Combinação dos balanços com tocar atrás.</td></tr>
<tr><td rowspan="4">Final</td><td>1. Mobilização dos ombros: flexão e extensão dos braços.</td><td rowspan="4">• Adoptar o alinhamento neutro de forma autónoma, sem qualquer apoio externo enquanto realiza movimentos dos MI e MS.
• Conseguir mobilizar a coluna em todas as direcções mantendo a posição neutra da bacia e MI.
• Utilizar a respiração torácica.</td><td rowspan="4">1</td><td rowspan="4">4 – 6 seguindo o ritmo respiratório individual</td></tr>
<tr><td>2. Mobilização da coluna:
• Flexão do tronco na região dorsal com respiração torácica;
• Rotação lateral lenta com respiração torácica;
• Rotação do tronco com balanços laterais;</td></tr>
<tr><td>3. Mobilizar membro inferior:
• Mobilizar os pés;
• Mobilizar joelhos.</td></tr>
<tr><td>4. Respirações combinadas com alongamentos dinâmicos.</td></tr>
<tr><td colspan="5">Orientações gerais:
1. Iniciar os exercícios de transferência de peso a uma cadência de 2T e passar gradualmente a 4T em cada fase;
2. Ao longo deste mesociclo, devem ser introduzidos os mesmos exercícios de equilíbrio com os joelhos estendidos (extensão, enquanto acção?);
3. Para promover no aluno a identificação das aprendizagens sobre o seu corpo conseguidas em cada unidade de treino e permitir-lhes uma sensação de “êxito” e bem-estar, cada sessão deverá terminar com a repetição das acções de consciencialização postural, activação do “core”, respiração, mobilidade e estabilidade da coluna transmitidas na primeira parte, enfatizando o que conseguem fazer com maior facilidade (ex: “a flexão do tronco é mais fácil”; “conseguem sentir o que é o “cinto” – ou “core”).</td></tr>
</table>

Período 1 – mesociclo 2

Período 1 - mesociclo 2

Objectivo: aplicar as competências adquiridas de Controlo Postural durante no mesociclo 1 no desenvolvimento das seguintes componentes do treino:
1. **Força funcional (mobilidade e estabilidade):** desenvolvimento de uma técnica de execução eficiente e aumento da resistência muscular, com especial incidência nas acções relacionadas com tarefas do dia-a-dia (locomoção e transporte de objectos). 2. **Equilíbrio estático e dinâmico:** realização das tarefas anteriormente aprendidas com maior segurança e controlo da estabilidade. 3. **Função cardiovascular:** associada ao equilíbrio dinâmico, agilidade e coordenação.
Critérios de êxito gerais:
No final deste mesosciclo o aluno deverá ser capaz de: 1. Aplicar as competências de controlo postural adquiridas no mesociclo anterior em situações de equilíbrio dinâmico, de agilidade e de treino da força, sendo capaz de melhorar s níveis de força resistente ao nível dos membros inferiores em diferentes posições corporais (especificidade da tarefa). 2 Suportar progressivo aumento da carga de treino através de: • Aumento do número de repetições e de séries; • Modificação das cadências de execução (“concêntrico lento; “excêntrico lento”); • Aumento da Resistência externa; • Redução da base de apoio.
Orientações gerais:
1. As opções de execução deverão respeitar o nível de condição física dos participantes e/ou disponibilidade de material. 2. As progressões dos exercícios poderão ser alteradas pelo professor; no entanto, a ordem de execução deverá de ser mantida.

FASE INICIAL – 3’

Controlo Postural – posição bípede

Exercícios		Imagens	Critérios de êxito	séries	Reps / Veloc. Exec.
	2. Identificação da base de apoio.	**Pés**: Balançar peso sobre os pés em todas as direcções como um “sempre-em-pé”.	5. Utilizar a respiração torácica na maioria dos exercícios de força funcional; 6. Adoptar o alinhamento neutro de forma autónoma, sem qualquer apoio externo (ex: parede) enquanto realiza movimentos dos MI e MS; 7. Realizar movimentos dos MI e MS com menor base de apoio (sem parede ou outro); 8. Conseguir mobilizar a coluna em todas as direcções mantendo a posição neutra da bacia e MI.	1	4 – 6 de acordo com o ritmo respiratório individual
	7. Respiração	**Joelhos:** flexão/extensão, adução/abdução. **Bacia:** retroversão /anteversão,“Salsa”, “Ponteiros do Relógio”. **Omoplatas:** elevação/depressão; adução/abdução; rotação. **Cabeça:** “Imagine um boneco que só mexe a cabeça”.			
	8. Activação da Unidade Interna e mobilização da coluna Flexão lateral e Flexão/extensão.	**Resp. Abdominal ou Diafragmática:** “Encha a barriga como se fosse uma grávida”; “soprar as velas dos 90 anos”. **Resp. Torácica ou lateral com flexão lateral** Inspire na posição neutra - “Balão”; Expire enquanto flecte lateralmente o tronco e activa UI. “Árvore que se agita ao vento”; “Crescer”: **Flexão Anterior/Extensão** “Colar de pérolas” - activação dos músculos abdominais na flexão e extensores da coluna no regresso à posição inicial. **Rotação** Imagine que é toureiro que manipula a capa: “Olé”!			
	9. Alinhamento neutro enquanto se executam movimentos dos MS e MI.	**Membros Superiores:** Flexão dos braços – “levante uma caixa” Rotação externa - “Abra a cortina” Extensão – “Empurre a			

		parede" (mãos ou cotovelos". **Membros inferiores:** "Deslize na parede, com o peso distribuído sobre os pés"; "Não se sente na cadeira nem se ajoelhe"; "Eleve os calcanhares" (joelho estendidos); "Bata com os pés no chão" (joelhos flectidos). **Integração** Braços/pernas em simultâneo.			
Orientações gerais: 3. Nesta fase pretende-se que o aluno consiga aplicar as competências de controlo postural desenvolvidas no 1º mesociclo, sem ter de recorrer ao apoio da parede. 4. É igualmente objectivo desta fase da aula, promover a concentração do participante no controlo postural nas tarefas a seguir propostas					

FASE CARDIO – 10’	
Posição bípede – disposição em xadrez	
Exercícios	**Critérios de êxito**
Movimentos rítmicos estacionários: • Balanços (Bal) simples a combinar movimentos suaves de Braços - balançar frente/trás com mãos no ombro, balançar frente/trás com cotovelos semi-estendidos, pequenos círculos com mãos no ombro e com braços semi-estendidos (“pagaiar”, “lavar a roupa”, “tirar migalhas”, “nadar bruços”, “mexer panela”, “chicote”, etc.); • Balanços laterais (Bal ↑ ou↓) a variar movimentos de braços (acompanham o movimento de transferência lateral) - pêndulo, “alisar a água”, empurrar ao lado simples e duplo, “lançar a bola”, “onda”, etc; • Step-touch (ST) a variar os toques dos pés - cruza frente e atrás, eleva joelho simples e cruzado, eleva calcanhar atrás e à frente, etc.; • Step-touch (ST) com variações de amplitude e braços, ou; • Toques (Taps) variados (frente, lado, atrás, elevação de joelho, chutos, etc.) com variações de braços (exemplos anteriores); **Treino de marcha (Mc) estacionária:** • Variações nos apoios (afastados, juntos, “tandem”, elevação dos dedos, elevação dos calcanhares, agachado, apoio na parte externa/interna do pé); • Variação na amplitude - elevação dos joelhos; • Utilização de movimentos de braços (palmas, empurrar, puxar, “manguitos”, “laço”, “disco”, etc.).	• Realizar os movimentos rítmicos “a tempo”, numa cadência entre 124-128 BPM‘s, durante 10 min contínuos com uma intensidade leve-moderada (4-5 na EPSE); • Executar a marcha estacionária com segurança e estabilidade em todas as variações de apoios propostas; • Executar a marcha estacionária com segurança e estabilidade a elevar os joelhos (altura máx recomendada) durante 30s contínuos – 1 série.
Orientações gerais: 1. Nesta fase os braços devem acompanhar o movimento predominante do tronco e membro inferior, sendo estes realizados preferencialmente no plano sagital. 2. Podem ser utilizados alguns movimentos de circundução com baixa amplitude (mãos nos ombros, cotovelos semi-flectidos) para facilitar o aquecimento através mobilização articular dinâmica (não exceder as 6 reps neste tipo de movimentos).	

<table>
<tr><th colspan="5">FASE TRANSIÇÃO – 5’</th></tr>
<tr><th colspan="5">Equilíbrio - Posição bípede</th></tr>
<tr><th colspan="2">Exercícios</th><th>Critérios de êxito</th><th>séries</th><th>Reps / Veloc. Exec.</th></tr>
<tr><td rowspan="3">Transferências de apoio</td><td>2. Transferências de apoio simples com joelhos relaxados nas bases: “Afastada” “Frente/trás afastado” e “Unida”.</td><td rowspan="3">Realizar com sucesso as transferências de peso entre as posições “Base Afastada”, “Base Unida” e “T Afastado” com os joelhos relaxados, mantendo a estabilidade nos apoios e a postura neutra da coluna na posição bípede.</td><td rowspan="6">1 cada lado</td><td rowspan="3">2 reps de cada movimento completo a uma cadência de 4 T cada fase</td></tr>
<tr><td>3. Transferências de apoio com mudança de base nas posições:
• “Base Afastada” - “Base Unida” e caminho inverso;
• “Base em T Afastado” - “Base Unida” e caminho inverso.</td></tr>
<tr><td>4. Igual ao anterior mas com movimentos de braços e/ou cabeça.</td></tr>
<tr><td rowspan="3">Equilíbrio em apoio unipedal

(apoio das mãos na parede, cadeira, bastão ou num colega)</td><td>5. Deslizar um dos pés pelo chão no plano sagital sem perder o contacto com o solo.</td><td rowspan="3">Conseguir realizar os movimentos com apenas 1 das mãos apoiada mantendo a estabilidade nos apoios e a postura neutra da coluna na posição bípede.</td><td rowspan="3">4 reps a uma cadência de 4T/fase para cada lado (D/E)</td></tr>
<tr><td>6. Elevar o membro livre de forma a perder o contacto com o solo e retomar a posição inicial.</td></tr>
<tr><td>7. Realizar movimentos de flexão/extensão do joelho, mantendo a coxa alinhada com o membro de apoio, e retomar a posição inicial.</td></tr>
<tr><td colspan="5">Orientações gerais:
4. Iniciar todos os exercícios a uma cadência de 2T e passar gradualmente a 4T em cada fase;
5. Iniciar os movimentos em apoio unipedal com apoio das 2 mãos e, progressivamente, reduzir para apenas1 apoio.</td></tr>
</table>

FASE FORÇA FUNCIONAL					
Posição de 4 apoios (apoio na parede, cadeira ou solo) **– 5’**					
Exercícios		**Imagens**	**Critérios de êxito**	**séries**	**Reps / Veloc. Exec.**
	1. Mobilização da coluna e identificação da posição neutra: “Gato-Camelo”; “Tampo de Mesa.	Deverão ser utilizadas as imagens indicadas para esta posição no 1º mesociclo.	1. , Mobilizar a coluna e regressar á posição neutra de forma autónoma, sem modificar a distribuição do peso nos apoios 2. Equilibrar um bastão nas costas.	1 De cada opção	6 – 8 de acordo com o ritmo respiratório individual
	2. “Super-homem modificado”- -Extensão do MI.	“Coice” - pé elevado do solo, um objecto em equilíbrio nas costas.	Realizar uma série de 6-8 repetições mantendo o alinhamento neutro.		
	3. “Super-Homem modificado” - Extensão/flexão MS.	“empurrar água da piscina para trás”.	Manter a posição neutra (coluna, cinturas) enquanto realiza movimento dos membros superiores, com apoio de antebraços ou mãos no solo ou na cadeira Capaz de manter a posição de maior desequilíbrio durante 2 ciclos respiratórios consecutivos.		
	4. “Super-Homem modificado” - Flexão do MS.	“Levantar areia do chão”.			
	5. Abducção/ Aducção MS.	“Imagine que está a voar com um só braço”.			
	6. “Super-Homem” – extensão MI com flexão MS oposto.	Acção integrada de extensão do MI e flexão MS.	Conseguir realizar o exercício, equilibrando um objecto nas costas.		

Orientações gerais:

1. Neste mesociclo pretende-se que o aluno realize as mesmas acções do mesociclo anterior mas com apoio de mãos no solo. As situações especiais (síndroma do túnel cárpico; epicôndilite, lesões do ombro, patologias da coluna, coxo-femural ou joelho) poderão requerer o apoio da parede, cadeira ou outra superfície elevada, respeitando o nível de funcionalidade do participante.
2. Deverá, ainda, integrar uma fase isométrica nas posições de maior desequilíbrio (“Super-Homem”), aumentando a intensidade da participação na musculatura estabilizadora.
3. A selecção dos exercícios poderá ser alterada por o professor, devendo ser mantida a ordem.

FASE FORÇA FUNCIONAL

Posição decúbito dorsal (DD) – 10’

Exercícios		Imagens	Critérios de êxito	séries	Reps / Veloc. Exec.
 	1. **“Ponte de ombros”** • Simples com MS apoiados no solo, seguida de Toe Raise (TR) e Calf Raise (CR) na posição inicial; • Sem apoio dos MS no solo (mãos na direcção do tecto).	Utilizar as imagens indicadas para o 1º mesociclo	Realizar correctamente 1 série de 8-12 reps da **“Ponte de ombros” sem apoio** dos MS na cadência e intensidade definidas seguida de uma série de Calf Raise/Toe Raise na posição neutra	2 PO 1 TR CR	8-12 reps, cadências 4x4; 2x2 Intensidade 3-5 ESPE
	2. **“Chest Press”** com halteres ou banda elástica, adução horizontal do braço e extensão do antebraço.	Coluna e cinturas neutras, “desenhe” um arco com as mãos, mantendo-as na linha do peito.	Manter posição neutra enquanto realiza 2 séries de 8-12 reps do movimento de MS na cadência e intensidade definidas.	2	8-12 reps, cadência 2x2 intensidade 3-5 ESPE
   	**3. “Toe taps”** • Modificado (1) Marchar deitado. (2) Extensão da perna: • Manter MI na posição elevada (ângulo de 90º com a bacia)*- posição estática: • “Clássico” com MS elevados do solo.	• “Marchar deitado” • Pontapé” • Manter os MI elevados como se estivesse caído numa cadeira; • Descer o MI, como se os dedos tocassem no solo.	Realizar correctamente no mínimo 8 reps de: • “toe taps” modificado” (1) e (2), mantendo a posição neutra da coluna e cinturas enquanto realiza os movimentos e mantém respiração torácica; • Conseguir manter MI elevados durante 4 ciclos respiratórios	1 de cada opção	6-8 reps cadência 4x4 intensidade 3-5 da ESPE Posição estática –MI elevados: *2 a 4 ciclos respiratórios
	**2. “Rotação de Bacia”**	Contrair os oblíquos para rodar a bacia, mantendo os joelhos	Manter as omoplatas e os MS estáveis, enquanto realiza rotação da bacia e dos MI.	1	8 reps alternadas cadência 4x4 intensidade 2-4 da ESPE

		unidos e as omoplatas e os braços no solo”			

Orientações gerais:

1. Os exercícios 1, 2 e 3 são obrigatórios para o cumprimento dos critérios de êxito deste mesociclo.
2. A selecção dos exercícios poderá ser alterada pelo professor, de acordo com o nível de CF do participante.
3. O exercício Toe Taps “clássico” só deverá ser executado se o participante conseguir controlar a estabilidade lombo-pélvica, i.e.,activando o core e realizando um correcto padrão respiratório (ver capítulo 4 – Situações Especiais).

FASE FORÇA FUNCIONAL

Posição decúbito lateral (DL) – 2’5´´ cada lado (5’ total)

Exercícios		Imagens	Critérios de êxito	séries	Reps / Veloc. Exec.
	1. **“Ostra”**- sem apoio do MS livre.	Utilizar as imagens indicadas no primeiro mesociclo.	Manter posição neutra, enquanto realiza os exercícios por 8 reps consecutivas, **sem apoio** do membro superior livre.	1 de cada opção	6-8 reps de acordo com o ritmo respiratório individual
	2. **“Círculos”** – sem o apoio do MS livre.	Utilizar as imagens indicadas no primeiro mesociclo.			
	3. **“Extensão/Flexão”** do MI livre paralelo ao solo e com o pé em dorsi-flexão: • Com apoio do MS livre; • Sem apoio do MS livre.	Utilizar as imagens indicadas no primeiro mesociclo, enfatizando a semelhança entre este movimento integrado e a estabilidade exigida no “Super-Homem”.			

Orientações gerais:

1. Começar para um dos lados e alternar com posição deitada ou 4 apoios.
2. A selecção dos exercícios e respectivas progressões poderão ser modificadas pelo professor, de acordo com as sugestões apresentadas e o nível de aptidão funcional do participante.

FASE FORÇA FUNCIONAL

Posição bípede – 10’

Exercícios		Imagens	Critérios de êxito	séries	Reps / Veloc. Exec.
	**“Agachamento”** **Da 1ª e 2ª sessão:** • Realizar o movimento com apoio na parede; .	“Escorregar na parede como se fosse sentar-se numa cadeira”	Executar o exercício **sem o apoio da parede** durante 12 repetições, mantendo o alinhamento neutro (coluna, cinturas e MI).	2	8-12 reps, cadência 2x2, 4x4 intensidade 3-5 ESPE
	**Da 4ª à 5ª sessão** Mesmo movimento mantendo uma bola entre o sacro e a parede e mantendo o alinhamento neutro da coluna/bacia				
	**Da 6ª e 7ª sessão** Deslizar na parede (sem bola) e inclinar o tronco a partir da articulação coxo-femural;				
	**8ª e 9ª sessão** A mesma acção mas sem apoio da parede				
	“**Remada Baixa**” **Da 1ª à 5ª sessão** Com apoio da bacia na parede, em posição de agachamento, realizar o movimento **sem resistência;**	“Escorregar na parede” até à posição de agachamento e inclinar tronco a partir da art. Coxo-femural, mantendo a coluna neutra.	Executar o exercício com apoio da parede mantendo o alinhamento neutro (coluna, cinturas e MI) durante 12 repetições com o uso de resistência.	2	
	Da 6ª á 9ª sessão Na mesma posição, **com resistência externa** (halteres ou elástico).				

Orientações gerais:

1. O exercício “Remada Baixa” poderá ser realizado na posição sentada (cadeira ou step) ou bípede (elástico ou halteres).
2. A selecção dos exercícios poderá ser alterada pelo professor, de acordo com o nível de aptidão funcional do participante.

FASE FINAL				
Posição bípede – 5' **Consciencialização Final**				
Exercícios		**Critérios de êxito**	**séries**	**Reps / Veloc. Exec.**
  	1. **Flexibilidade activa** das principais regiões musculares: • Com ajuda da banda ou toalha; OU Sem ajuda externa.	Mobilizar activamente, com ou sem ajuda externa, as principais articulações envolvidas nas acções propostas: • Coxo-femural; Joelho,Tornozelo; • Ombro; • Coluna.	1	4 – 6 de acordo com o ritmo respiratório individual
	2. Repetir **rotina de consciencialização postural executada na fase inicial** da aula, enfatizando a mobilidade e estabilidade da coluna e o alinhamento neutro associado a um correcto padrão respiratório.	Executar de forma eficiente a rotina de consciencialização, adquirindo o alinhamento neutro.		

Orientações gerais:

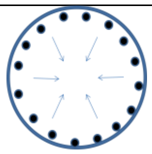
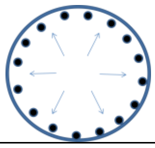
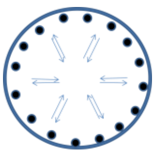
1. O apoio da parede deverá evoluir para "sem apoio".
2. O método utilizado para o treino da flexibilidade activa baseia-se na repetição do gesto por acção dos músculos agonistas e exige, simultaneamente, a estabilidade nos segmentos de apoio.
3. Tal como no primeiro mesociclo, esta fase tem por objectivo promover no aluno a identificação das aprendizagens sobre o seu corpo conseguidas em cada sessão de treino.

Período 1 – mesociclos 3 & 4

Período 1 - mesociclos 3 & 4

Objectivo: Aplicar as competências adquiridas ao nível do Controlo Postural durante º 2º mesociclo no desenvolvimento das seguintes componentes do treino:
4. **Força funcional (mobilidade e estabilidade):** consolidação das competências adquiridas nos mesociclos anteriores através do: • Aumento da sobrecarga; • Aumento da participação musculatura estabilizadora, sobretudos ao nível do membros inferiores, bacia e core. 5. **Equilíbrio estático e dinâmico:** realização das transferências de apoio em cadências mais lentas, e aumento da instabilidade através da retirada do apoio das mãos nos movimentos em apoio unipedal; 6. **Função cardiovascular:** realização das tarefas anteriormente aprendidas com aumento na exigência ao nível psicomotor, através da introdução de variantes de deslocamento e de complexidade, introdução dos movimentos de "trabalho de pés".
Critérios de êxito gerais:
No final deste mesosciclo o aluno terá ser capaz de executar com eficácia, tarefas mais exigentes ao nível da produção de força, equilíbrio, agilidade e locomoção.
Orientações gerais:
3. As opções de execução deverão respeitar o nível de condição física dos participantes e/ou disponibilidade de material. 4. As progressões dos exercícios poderão ser alteradas pelo professor; no entanto, a ordem de execução deverá de ser mantida.

<table>
<tr><th colspan="6">FASE INICIAL – 3’</th></tr>
<tr><th colspan="6">Controlo Postural – posição bípede</th></tr>
<tr><th colspan="2">Exercícios</th><th>Imagens</th><th>Critérios de êxito</th><th>Séries</th><th>Reps / Veloc. Exec.</th></tr>
<tr><td rowspan="4"></td><td>3. Identificação da base de apoio e da posição de cada segmento corporal</td><td rowspan="4">As imagens utilizadas serão as indicadas nos mesociclos anteriores acrescidas de manipulação da banda</td><td rowspan="4">9. Adoptar o alinhamento neutro de forma autónoma, sem qualquer apoio externo (ex: parede) enquanto realiza movimentos dos MI e MS.
10. Realizar movimentos dos MI e MS com menor base de apoio (sem parede ou outro apoio).
11. Conseguir mobilizar a coluna em todas as direcções mantendo a posição neutra da bacia e MI</td><td rowspan="4">1</td><td rowspan="4">6-8
De acordo com o ritmo respiratório individual</td></tr>
<tr><td>10. Respiração, Activação da Unidade Interna.</td></tr>
<tr><td>11. Mobilização da coluna:
-Flexão lateral
-Flexão/extensão
-Rotação</td></tr>
<tr><td>12. Alinhamento neutro enquanto se executam movimentos dos MS e MI:
• Rotação externa+1/2 agachamento;
• Flexão dos MS com Calf Raise;
• 1/2 Agachamento com toe raise</td></tr>
<tr><td colspan="6">Orientações gerais:
5. A rotina inicial de consciencialização postural é realizada com a manipulação de uma banda ou toalha. Nesta fase da aula, a banda não será usada como resistência externa, mas sim como auxiliar na promoção da amplitude do movimento e, simultaneamente, da estabilidade da cintura escapular e articulações do MS.</td></tr>
</table>

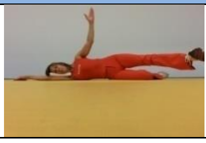
<table>
<tr><th colspan="3">FASE CARDIO – 10’</th></tr>
<tr><th colspan="3">Posição bípede – disposição em círculo</th></tr>
<tr><th>Exemplos de deslocamento</th><th>Exercícios</th><th>Critérios de êxito</th></tr>
<tr><td></td><td>Treino de marcha (Mc) estacionária:
variações nos apoios;
variação na amplitude;
utilização de movimentos de braços.</td><td rowspan="5">Realizar todos os movimentos “a tempo”, numa cadência entre 124-128 BPM‘s, durante 10 min contínuos com uma intensidade moderada (5-6 na EPSE);
Executar os movimentos estacionários com segurança e estabilidade em todas as variações propostas;
Executar os movimentos em deslocamento com segurança e estabilidade em todas as variações propostas;
Realizar o “trabalho de pés” com segurança e estabilidade em 3 séries alternadas de 30s cada (elevação dos dedos x elevação dos pés)</td></tr>
<tr><td>
</td><td>Treino de marcha (Mc) em deslocamento:
marchar para frente (fechar o círculo), fazer meia-volta, marchar para frente a voltar para o lugar (abrir o círculo);
marchar para frente (fechar o círculo), marchar para trás a voltar para o lugar (abrir o círculo);
idem com maior amplitude (para frente);
idem com maior velocidade (para frente).</td></tr>
<tr><td></td><td>Movimentos rítmicos estacionários:
Toques (Taps) variados com variações de amplitude e braços;
Step-touch (ST) com variações de amplitude e braços;</td></tr>
<tr><td>
</td><td>Movimentos rítmicos em deslocamento
Duplo Step-touch (DST) simples;
DST a variar amplitude: afasta mais os apoios, em agachamento;
Multiplos ST (MST) simples;
MST com variações de amplitude;
DST e MST a variar deslocamentos:
mudar sentido: horário / anti-horário;
em fila para dentro e para fora;
virados para o centro / virado para fora do círculo</td></tr>
<tr><td></td><td>“Trabalho de pés” (footwork)
Elevação dos calcanhares alternada lenta e “a tempo”;
Elevação dos calcanhares simultânea “a tempo”;
Elevação dos dedos alternada lenta e “a tempo”;
Elevação dos dedos simultânea “a tempo”;
“rolamento do pé” na marcha do tipo “piaffé” lenta e “a tempo”.</td></tr>
<tr><td colspan="3">Orientações gerais:<ol start="3">
Nesta fase, o objectivo é aumentar a exigência ao nível psicomotor, através da introdução de variantes de deslocamento e de complexidade que irão promover estímulo na lateralidade, estruturação espaço-temporal e coordenação motora global;
Os novos deslocamentos devem ser introduzidos gradualmente a cada aula;
O professor deverá garantir a segurança na realização dos novos deslocamentos, evitando situações de risco ao enfatizar a atenção dos participantes relativamente ao espaço circulante, e ao utilizar instrução verbal e gestual reforçada;
Os novos movimentos (DST e MST) deverão ser introduzidos inicialmente sem variações nos deslocamentos.</td></tr>
</table>

<table>
<tr><th colspan="5">FASE TRANSIÇÃO – 5’</th></tr>
<tr><th colspan="5">Equilíbrio - Posição bípede (disposição em círculo ou livre em xadrez)</th></tr>
<tr><th colspan="2">Exercícios</th><th>Critérios de êxito</th><th>séries</th><th>Reps / Veloc. Exec.</th></tr>
<tr><td rowspan="3">Transferências de apoio</td><td>3. Transferências de apoio simples com joelhos relaxados, e depois estendidos, nas bases: “Afastada”, “Frente/trás afastado” e “Unida”.</td><td rowspan="3">Realizar com sucesso as transferências de peso entre as posições “Base Afastada”, “Base Unida” e “T Afastado” com os <u>joelhos estendidos</u>, mantendo a estabilidade nos apoios e a postura neutra da coluna na posição bípede</td><td rowspan="6">1 cada lado</td><td rowspan="3">2 reps de cada movimento completo a uma cadência de 8 T cada fase</td></tr>
<tr><td>5. Transferências de apoio com mudança de base nas posições:
• “Base Afastada” - “Base Unida” e caminho inverso;
• “Base em T Afastado” - “Base Unida” e caminho inverso.</td></tr>
<tr><td>6. Igual ao anterior mas com movimentos de braços e/ou cabeça</td></tr>
<tr><td rowspan="3">Equilíbrio em apoio unipedal (sem apoio das mãos)</td><td>8. Deslizar um dos pés pelo chão no plano sagital e frontal sem perder o contacto com o solo</td><td rowspan="3">Conseguir realizar os movimentos sem apoio das mãos, e com o pé livre em contacto com o solo, mantendo a estabilidade nos apoios e a postura neutra na posição bípede</td><td rowspan="3">4 reps a uma cadência de 4T/fase para cada lado (D/E)</td></tr>
<tr><td>9. Elevar o membro livre no plano sagital e frontal de forma a perder o contacto com o solo e retomar a posição inicial</td></tr>
<tr><td>10. Realizar movimentos circulares a deslizar o pé do membro livre pelo chão (Ex: desenhar um círculo no chão):
• Variar o sentido;
• Variar amplitude;
• Tentar elevar o pé do solo.</td></tr>
<tr><td colspan="5">Orientações gerais:
6. Nesta fase deve-se aumentar a duração das transferências de apoio, de forma a passar gradualmente dos 4T para 8T em cada fase;
7. Iniciar os movimentos de equilíbrio em apoio unipedal com contacto do pé do membro livre com o solo, e permitir que os participantes mais aptos realizem os movimentos sem contacto com o solo.</td></tr>
</table>

FASE FORÇA FUNCIONAL					
Posição de 4 apoios (apoio na parede, cadeira ou solo) **– 5'**					
Exercícios		**Imagens**	**Critérios de êxito**	**Séries**	**Reps / Veloc. Exec.**
	3. Mobilização da coluna e identificação da posição neutra: -"Gato-Camelo"; -"Tampo de Mesa.	Deverão ser utilizadas as imagens indicadas para esta posição no 1º mesociclo.	7. Mobilizar a coluna e regressar á posição neutra de forma autónoma sem modificar a distribuição do peso nos apoios; 8. Equilibrar um bastão nas costas.	1	
	4. "Remada baixa":com haltere.	"Mantendo a posição neutra das cinturas e coluna, "puxe" o haltere na direcção das costelas com o cotovelo para cima.	9. Realizar uma série de 6-8 repetições, mantendo o alinhamento neutro		8 reps, cadência s 4x4; 2x2 Intensida de 3-4 ESPE
	10. "Super-Homem" – extensão MI com flexão MS oposto	Acção integrada de extensão do MI e flexão MS	Manter a posição neutra (coluna, cinturas) enquanto: a) Realiza movimento opostos dos MS e MS, b) com apoio de mãos, no solo e é capaz de manter a posição a posição de "Prancha" durante 2 ciclos respiratórios.		8 reps, cadência 2x2 Intensida de 3-4 ESPE
	11. Preparação para "Prancha"	Com mãos sobre uma superfície arredondada (toalha, rolo ou haltere, activar o core e elevar os joelhos mantendo a coluna e cinturas neutras.			8 reps, cadência 4x4;2x2 Fase estática (2 ciclos resp.) Intensida de 3-5 ESPE
	12. Prancha	Mãos sobre uma superfície elevada, elevar os joelhos do solo e estende-los até à posição de prancha.			2-4 reps com uma fase estática durante 2 ciclos respira-Tórios.

Orientações gerais:

4. O aumento da exigência das tarefas propostas deve ser adaptado ao nível aptidão funcional e patologias osteo-articulares de cada participante.

<table>
<tr><th colspan="6">FASE FORÇA FUNCIONAL</th></tr>
<tr><th colspan="6">Posição decúbito lateral (DL) – 2’5´´ cada lado (5’ total)</th></tr>
<tr><th colspan="2">Exercícios</th><th>Imagens</th><th>Critérios de êxito</th><th>séries</th><th>Reps / Veloc. Exec.</th></tr>
<tr><td></td><td>4. Círculos” – sem o apoio do MS livre</td><td rowspan="2">Utilizar as imagens indicadas no primeiro mesociclo.</td><td rowspan="3">Manter posição neutra, enquanto realiza os exercícios por 8 reps consecutivas, sem apoio do membro superior livre.</td><td rowspan="3">1</td><td rowspan="2">6-8 reps de acordo com o ritmo respiratório individual</td></tr>
<tr><td></td><td>5. “Extensão/Flexão” do MI livre paralelo ao solo e com o pé em dorsi-flexão:
• Com apoio do MS livre
• Sem apoio do MS livre</td></tr>
<tr><td>
</td><td>• Preparação para “Prancha Lateral:
(1) Apoio de antebraço.
(2) Estabilização da omoplata;
(3) Activação do “core”.</td><td>“Imagine que está na praia e quer espreitar o mar ao longe”.</td><td>Prancha Lateral

2-4 reps. Posição estática mantida durante 2 -4 ciclos respiratórios</td></tr>
<tr><td colspan="6">Orientações gerais:
3. Começar para um dos lados e alternar com posição deitada ou 4 apoios.
4. A selecção dos exercícios e respectivas progressões poderão ser modificadas pelo professor, de acordo com o nível de aptidão funcional e limitações ósteo-articulares do participante.</td></tr>
</table>

FASE FORÇA FUNCIONAL					
Posição bípede – 10’					
Exercícios		**Imagens**	**Critérios de êxito**	**séries**	**Reps / Veloc. Exec.**
 	**1. “Agachamento”** Sem apoio da parede e com resistência externa (halteres – “sacos das compras”)	“Sentar na cadeira, mantendo coluna neutra e utilizando a respiração torácica”.	Executar o exercício **sem o apoio da parede** durante, 3 séries de 12 repetições, mantendo o alinhamento neutro (coluna, cinturas e MI).	3	10-12 reps, cadência 2x2, 4x4, 3x1 intensidade 4-6 ESPE
	**2. “Remada Baixa”** Sem apoio da parede e com resistência externa (halteres ou elástico)	Imagine que vai buscar um saco ao chão. Mantenha a coluna neutra, flectindo a articulação coxo-femural.	Executar o exercício sem o apoio da parede mantendo o alinhamento neutro (coluna, cinturas e MI) durante 2 séries de 12 repetições com o uso de resistência externa.		

Orientações gerais:

3. O exercício “Remada Baixa” poderá ser realizado na posição sentada (cadeira ou step) ou bípede (elástico ou halteres).
4. A selecção dos exercícios poderá ser alterada pelo professor, de acordo com o nível de aptidão funcional do participante.

<table>
<tr><th colspan="6">FASE FINAL</th></tr>
<tr><th colspan="6">Posição bípede – 5’
Consciencialização Final</th></tr>
<tr><th colspan="2">Exercícios</th><th>Imagens</th><th>Critérios de êxito</th><th>séries</th><th>Reps / Veloc. Exec.</th></tr>
<tr><td>
</td><td>3. Flexibilidade activa das principais regiões musculares:
• Com ajuda da banda ou toalha
• OU Sem ajuda externa</td><td>“use os seus músculos para mover os diferentes segmentos corporais. A banda ou toalha são apenas auxiliares”!</td><td rowspan="2">Mobilizar activamente, com ou sem ajuda externa, as principais articulações envolvidas nas acções propostas:
• Coxo-femural, Joelho,Tornozelo;
• Ombro;
• Coluna.</td><td rowspan="2">1</td><td rowspan="2">4 – 6 de acordo com o ritmo respiratório individual</td></tr>
<tr><td></td><td>4. Sem apoio da parede rotina de consciencialização postural executada na fase inicial da aula enfatizando a mobilidade e estabilidade da coluna, o alinhamento neutro associado a um correcto padrão respiratório</td><td>“use os seus músculos para mover os diferentes segmentos corporais”
“Sinta como os seus movimentos estão mais amplos e fáceis relativamente ao inicio da aula!”</td></tr>
<tr><td colspan="6">Orientações gerais:
4. O apoio da parede deverá evoluir para a mesma rotina, “sem apoio”.
5. O método utilizado para o treino da flexibilidade activa baseia-se na repetição do gesto por acção dos músculos agonistas, exigindo, simultaneamente, a estabilidade nos segmentos de apoio.
6. Tal como no primeiro mesociclo, esta fase tem por objectivo promover no aluno a identificação das aprendizagens sobre o seu corpo conseguidas em cada sessão de treino.</td></tr>
</table>

Período 2 – mesociclos 1 & 2

Período 2 - mesociclos 1 & 2

Objectivo: desenvolvimento das seguintes componentes do treino:
7. **Força funcional (mobilidade e estabilidade):** • Aumento da sobrecarga através do número de séries, modificação da cadência de execução (concêntrico lento, excêntrico lento, fase isométrica) e organização dos exercícios (método de pré-exaustão); • Introdução de novos exercícios em diferentes posturas: bípede (Afundo), 4 apoios (Prancha de antebraços e Push up) e deitada (Pullover, Ponte com um apoio) • Introdução ao treino integrado – exercício na posição de decúbito dorsal (Integração de Pullover com Toe Taps); 8. **Equilíbrio estático e dinâmico:** reforço das competências desenvolvidas nos mesociclos anteriores, aumentando a exigência das acções em equilíbrio dinâmico através de: • Associação ao treino de força dos membros inferiores • Modificação da velocidade de execução (equilíbrio dinâmico versus equilíbrio estático) 9. **Função cardiovascular:** realização das tarefas anteriormente aprendidas com aumento da intensidade fisiológica através de • Variação da amplitude dos movimentos anteriormente aprendidos; • Integração de movimentos com impacto; • Deslocamentos integrando ações de “travagem”; • Aumento da exigência (número de séries, repetições e equilíbrio) nos movimentos de “trabalho de pés”.
Critérios de êxito gerais:
No final deste mesociclo o aluno terá ser capaz de executar, com eficácia, tarefas mais exigentes com especial ênfase no aumento da força e equilíbrio dinâmico.
Orientações gerais:
5. As opções de execução deverão respeitar o nível de condição física dos participantes e/ou disponibilidade de material. 6. As progressões dos exercícios poderão ser alteradas pelo professor; no entanto, a ordem de execução deverá de ser mantida.

FASE INICIAL – 1-3’

Checklist postural – posição bípede

Exercícios

6. Identificação da base de apoio e da posição de cada segmento corporal
7. Respiração, Activação da Unidade Interna.
8. Mobilização da coluna
9. Movimentos dos Membros Superiores (MS) e Membros Inferiores (MI)

Orientações gerais:

1. A rotina inicial de consciencialização postural passa a ser mais curta, servindo como preparação psicológica, concentração, e mentalização para o controlo postural durante os movimentos na aula. O professor deverá aproveitar para enfatizar os objectivos da aula e solicitar aos alunos que “analisem” o seu estado inicial, ex: “Identifiquem as zonas do corpo que apresentam maior tensão: pés, joelhos, coluna, ombro”. O mesmo exercício de “checklist” deverá ser integrado no final da aula.
2. Poderá utilizar a banda ou toalha como auxiliar na promoção da amplitude do movimento e, simultaneamente, da estabilidade articular do MS (não como resistência externa).

FASE CARDIO – 12-15’

Posição bípede – disposição livre

<table>
<tr><th>Exercícios</th><th>Critérios de êxito</th></tr>
<tr><td>

Treino contínuo variado / intervalado

1) Períodos de esforço:
   - Treino de marcha (Mc) em deslocamento
     - ✓ A variar amplitude, velocidade, direcção;
     - ✓ Combinar com travagens e mudanças rápidas de direcção;
   - Movimentos rítmicos em deslocamento
     - ✓ Duplo Step-touch (DST) com variações de amplitude e de impacto;
     - ✓ Multiplos ST (MST) com variações de amplitude, Shuflle;
   - Movimentos rítmicos estacionários
     - ✓ Toques (Tq) e Step-touch (ST) com variações de impacto (pony, “pulse”, pêndulo);
     - ✓ Tq e ST com variações de amplitude (slide, afundos, “patinador no gelo”);
     - ✓ MC com elevação dos joelhos;
2) Períodos de recuperação:
   - Marcha (Mc) estacionária com variações nos apoios;
   - Tq e ST com manipulação de objectos (toalha, bolas, balões);
   - “Trabalho de pés” (footwork)
     - ✓ Elevação dos calcanhares alternada e simultânea “a tempo”;
     - ✓ Elevação dos dedos alternada e simultânea “a tempo”;
     - ✓ Marcha do tipo “piaffé” “a tempo”.

</td><td>

- Realizar todos os movimentos “a tempo”, numa cadência entre **<u>128-130</u>** BPM‘s, durante **<u>12-15</u>** min, com intensidade variada (7-8 nos períodos de esforço e 5-6 nos períodos de recuperação);
- Incluir 1- 2 min de marcha com os joelhos elevados sem pausas x 2 séries
- Executar os movimentos com segurança e estabilidade em todas as variações propostas;
- Realizar o “trabalho de pés” com segurança e estabilidade em **3 X 30s** cada (alternar séries de calf raise e toe raise);
- Executar a marcha do tipo “piaffé” a tempo durante **1 minuto**

</td></tr>
</table>

Orientações gerais:

1. Nesta fase, o objectivo é aumentar a intensidade do estímulo cardiovascular, através da manipulação das seguintes variáveis: velocidade de execução, movimentos com maior amplitude, introdução de deslocamentos e introdução de movimentos com impacto médio. A intensidade deve oscilar entre 7-8 na Escala Subjetiva de Perceção de Esforço (ESPE). média a elevada, nos períodos de esforço e baixa-média (5-6 na EPSE) nos períodos de recuperação;
2. Os movimentos laterais de maior intensidade (DST e MST) devem ser mais utilizados nesta fase, tendo o cuidado de introduzir as variações nos deslocamentos com segurança. Para evitar situações de risco deve-se chamar a atenção dos participantes relativamente ao espaço circulante, utilizando instrução verbal e gestual reforçada

<table>
<tr><th colspan="5">FASE TRANSIÇÃO – 5’</th></tr>
<tr><th colspan="5">Equilíbrio - Posição bípede</th></tr>
<tr><th colspan="2">Exercícios</th><th>Critérios de êxito</th><th>séries</th><th>Reps / Veloc. Exec.</th></tr>
<tr><td rowspan="2">Transferências de apoio + equilíbrio em apoio unipedal (sem apoio das mãos)</td><td>1. Transferências de apoio combinadas com equilíbrio em apoio unipedal:
• “Base Afastada” passa para “Base Unida”, elevando um apoio do solo e mantendo a posição durante 2s e realiza o caminho inverso;
• Idem da “Base em T Afastado” para “Base Unida” e caminho inverso.</td><td rowspan="2">• Realizar com sucesso as transferências de apoio combinadas com equilíbrio em apoio unipedal entre as posições “Base Afastada”, “Base Unida” e “T Afastado”, mantendo a estabilidade nos apoios e a postura neutra da coluna na posição bípede;

• Conseguir realizar os movimentos de equilíbrio unipedal sem apoio das mãos, e com o pé livre a perder o contacto com o solo, mantendo a estabilidade nos apoios e a postura neutra na posição bípede</td><td rowspan="2">1 cada lado</td><td>2 reps de cada movimento completo a uma cadência de 8T/fase</td></tr>
<tr><td>2. Realizar movimentos circulares a deslizar o pé do membro livre pelo chão (Ex: desenhar um círculo no chão):
• Variar o sentido;
• Variar amplitude;
• Elevar o pé do solo.</td><td></td></tr>
<tr><td colspan="5">Orientações gerais:
8. Nesta fase as transferências de apoio devem ser lentas, a durar <u>8T em cada fase</u>;
9. Realizar os movimentos de equilíbrio em apoio unipedal <u>sem contacto do pé do membro livre com o solo</u>. Permitir que os participantes menos aptos realizem os movimentos com o pé em contacto com o solo.</td></tr>
</table>

FASE FORÇA FUNCIONAL

Posição de 4 apoios (apoio na parede, cadeira ou solo) – 5'

Checklist postural – realizar o exercício "Gato" – "Camelo" – "Neutro"

4/5 ciclos respiratórios

Exercícios		Imagens	Critérios de êxito	Séries Reps / Veloc. Exec.
	1. **Prancha de mãos** numa superfície elevada	• Com apoio das mãos na cadeira (ou outra sup. elevada), elevar os joelhos do solo e estendendo-os até o corpo assumir a posição de prancha; • Manter o abdominal contraído, "cinto apertado", ombros longe das orelhas. Evite a hiperextensão dos cotovelos.	**1ª e 2ª semanas:** Mãos numa superfície elevada; Manter a posição neutra (coluna, cinturas) enquanto executa **4 reps** da "prancha de mãos" mantendo a posição durante 2 ciclos respiratórios. **3ª e 4ª semanas**: a mesma acção mas com mãos numa posição mais baixa: step ou solo.	• 3 séries • 4-6 reps • manter 2 ciclos respiratórios, na posição estática • (Intensidade 4-6 EPSE)
 	2. **Prancha** de antebraços	• Igual o anterior mas com apoio dos antebraços numa superfície elevada	Manter a posição neutra (coluna, cinturas) enquanto executa **2 reps** da "prancha de antebraços" e mantém a posição durante 2 ciclos resp.	• 2 séries • 2-4 reps • cadência 2X2 • mantém 2 ciclos resp. na fase estática • (Intensidade 4-5 EPSE)
  	3. **"Push-up"** (mãos numa sup. elevada) com uma fase estática na posição de **prancha de mãos**	• Imaginar o corpo como o "tampo de mesa" onde só os braços se movem ; • Manter o abdominal contraído, "cinto apertado", omoplatas longe das orelhas. Mãos alinhadas com os ombros, cotovelos a 90º ou junto ao tronco. Evitar a hiperextensão dos cotovelos quando se eleva do solo.	**1ª-3ª semanas:** Executar correctamente **4 reps** de push-up, mantendo a coluna e cinturas neutras durante todo o movimento, e no final da última rep. manter a posição de "**prancha de mãos**" com joelhos flectidos, durante **2 ciclos resp**. **4ª semana:** Executar o mesmo exercício mas, na fase estática, realizar a extensão dos joelhos.	• 2 séries • 4-8 reps, cadência 2X2 mantém 2 ciclos resp. na fase estática • (Intensidade 4-7 EPSE).

Orientações gerais:

1. As opções de execução devem estar de acordo com o nível de condição física dos participantes, devendo ser respeitada a seguinte ordem de progressão: parede; cadeira, step ou solo.
2. A selecção dos exercícios poderá ser alterada mas a ordem de execução terá de ser mantida.

FASE FORÇA FUNCIONAL

Posição decúbito dorsal (DD) – 10’

	**Checklist postural** – “Activação do “core” e alinhamento neutro (“Kegle” e/ou “Finger tip Abdominals”, mobilização das omoplatas/ MS, mobilização MI) 4/5 ciclos respiratórios

Exercícios		Imagens	Critérios de êxito	Séries e Reps / Veloc. Exec.
 	**3. “Ponte de ombros”** • Sem apoio dos MS no solo; • Manter a posição e retirar um dos apoios de forma alternada	• “Imaginar que está deitado, a tentar fechar o fecho e a apertar o cinto de umas calças muito justas”; • De seguida, manter a posição e retire alternadamente um dos apoios do solo - “marchar deitado”.	Realizar correctamente 3 séries de **12 reps** da “Ponte de ombros” sem apoio dos MS No final de cada série, manter a posição e retirar alternadamente um dos apoios em **4 reps**	• **3** séries • **12-16** reps • Cadências 2x2, 1X3, 1X1 • Itens. **4-6** (ESPE)
	**4. “Pull-over”**	• Segurar os halteres imaginando que se tem uma caixa entre as mãos, MS esticados na direcção do tecto; • Sem fletir os cotovelos, fletir os braços até aproximar os halteres do solo, acima da cabeça. • Manter os ombros afastados das orelhas, coluna neutra, costelas e bacia estáveis no solo.	Realizar correctamente **12 reps** do exercício, mantendo o alinhamento das cinturas pélvica (sem acentuar a curvatura lombar e elevar as costelas) e escapular (não elevar os ombros) durante o movimento dos MS	• **2** séries • **10-12** reps, cadências **4X4, 2x2** • Intens. **4-6** (ESPE)
 	**5. “Toe taps”** (Clássico: • Com MS apoiados no solo; • Sem apoio MS • Associando o movimento do Pullover-sem carga externa	• Vamos manter os MI elevados como se estivesse apoiado numa cadeira; • Descer o MI, como se os dedos tocassem no solo. • Mantendo estável a bacia e coluna, descer um MI e, ao mesmo tempo “espreguiçar” os braços acima da cabeça.	**1ª e 3ª semanas:** Realizar 2 séries **12 reps**, mantendo a posição neutra da coluna e cinturas. No final, de cada série, manter os MI elevados e executar 4 reps de pullover, sem carga externa. **3ª e 4ª semanas**: Realizar 2 séries de 12 reps, da mesma ação com MS elevados. Na fase final de cada série, realizar, 4 reps do exercício integrado Pullover+Toe taps sem alterar o alinhamento neutro da coluna e cinturas.	• **2** séries • **8-12** reps, cadência **4X4, 2x2** • **Manter posição estática** • Itens. **4-6** (ESPE)
	**6. “Tríceps à testa”**	• Segurar os halteres na direcção do tecto e flectir o cotovelo levando os halteres até à testa. • Não deixar os cotovelos descer para o tronco!	Realizar correctamente **12 reps** do exercício, mantendo o alinhamento das cinturas pélvica e escapular durante o movimento dos MS	• **2** séries • **10-12** reps, cadências **4X4, 2x2** • Intens. **4-6** (ESPE)

	**7. “Oblíquos”** com as pernas apoiadas numa sup. elevada	• Deitar de barriga para cima, com a perna apoiada; • Com uma das mãos apoiada no joelho oposto, elevar o ombro do solo e “escorregar” a mão na direcção da perna; • O tronco vai girar para o lado, mas a bacia e as pernas devem manter-se apoiadas e fixas	Realizar correctamente **12 reps** do exercício, mantendo o alinhamento da cintura pélvica e cintura escapular oposta, bem como da coluna durante o movimento	• **2** séries • **10-12** reps, cadências **4X4, 2x2** • Intens. **4-6** (ESPE)

Orientações gerais:

1. As opções de execução devem estar de acordo com o nível de condição física dos participantes,
2. A selecção dos exercícios poderá ser alterada ou pelo professor, no entanto, a ordem de execução terá de ser mantida.

<table>
<tr><th colspan="5">FASE FORÇA FUNCIONAL</th></tr>
<tr><th colspan="5">Posição decúbito lateral (DL) – 2’5´´ cada lado (5’ total)</th></tr>
<tr><td></td><td colspan="4">Checklist postural – “Activação do “core” e alinhamento neutro durante 4 ciclos respiratórios</td></tr>
<tr><th colspan="2">Exercícios</th><th>Imagens</th><th>Critérios de êxito</th><th>séries
Reps /
Veloc. Exec.</th></tr>
<tr><td></td><td>1. Círculos” do MI livre sem o apoio do MS livre</td><td rowspan="3">Utilizar as imagens indicadas nos mesociclos anteriores.</td><td rowspan="3">Manter posição neutra, enquanto realiza os exercícios por 8 reps consecutivas, sem apoio do membro superior livre.</td><td rowspan="2">• 1 série
• 6-8 reps
• Velocidade de acordo com o ritmo respiratório individual</td></tr>
<tr><td></td><td>2. “Extensão/Flexão” do MI livre sem apoio do MS livre</td></tr>
<tr><td>
</td><td>3. Preparação para “Prancha Lateral:
a. Apoio de antebraço.
b. Estabilização da omoplata;
c. Activação do “core”.</td><td>• 1 série
• 2-4 reps.
• Manter posição estática durante 2 -4 ciclos respiratórios</td></tr>
<tr><td colspan="5">Orientações gerais:
5. Começar para um dos lados e alternar com posição deitada ou 4 apoios.
6. Este exercício poderá ser realizado em alternância com o exercício anterior.
7. A selecção dos exercícios e respectivas progressões poderão ser modificadas pelo professor, de acordo com o nível de aptidão funcional e limitações ósteo-articulares do participante.</td></tr>
</table>

FASE FORÇA FUNCIONAL

Posição bípede – 10’

Exercícios		Imagens	Critérios de êxito	Séries Reps / Veloc. Exec.
	**1. “Agachamento”** a. Normal com resistência externa (halteres) b. Dinâmico unilateral	• “Sentar na cadeira”, mantendo coluna neutra, peso corporal sobre os calcanhares e os joelhos não “avançam”.	Executar o exercício **sem o apoio da parede** durante, 3 séries de 12 repetições 1ª série Agachamento 2 apoios 2ª/3ª Série Equilíbrio sobre um MI na fase concêntrica.	• 3 séries • 12 reps • cadências 2x2, 3x1, 1x1 • intensidade 5-7 (EPSE)
	**2. “Remada Baixa”** sem apoio da parede e com resistência externa (halteres ou elástico)	• Imaginar que vai buscar um saco ao chão. • Manter a coluna neutra, e flectir a partir da coxa.	Executar **16 reps** do exercício **sem o apoio da parede,** mantendo o alinhamento neutro (coluna, cinturas e MI) com o uso de resistência externa.	• 2 séries • 12-16 reps • cadências 2x2, 3x1, 1x1 • intensidade 5-7 (EPSE)
 	**3. Preparação para “Afundos”**: a. Apoio das mãos na parede ou cadeira b. Estabilizar tronco e apoios c. Fletir MI	• Imaginar que se vai ajoelhar no chão. • O tronco deve fazer um movimento vertical ou com ligeira inclinação a partir da art. CF, o joelho MI da frente sem avançar	1ª e 2ª semanas: Realizar 2 séries de 12 repetições com apoio das mãos numa superfície estável e mantendo alinhamento da coluna e cinturas e MI 3ª e 4 ª semana Mesma açõa mas sem apoio	• 2 séries • 8-12 reps • cadências 4x4,2x2, 3x1 • intensidade 4-6 (EPSE)

Orientações gerais:

5. O exercício “Remada Baixa” poderá ser realizado na posição sentada (cadeira ou step), ou com apoio na parede, no caso dos participantes com problemas osteoarticulares que provoquem dor ou desconforto extremo nesta posição.
6. No exercício “Afundo” a amplitude e a alteração do apoio das mãos deverão ser adaptados às condições de específicas de cada participante.
7. A selecção dos exercícios poderá ser alterada, de acordo com o nível de aptidão funcional do participante mas a ordem de execução mantida.

<table>
<tr><th colspan="5">FASE FINAL</th></tr>
<tr><th colspan="5">Posição bípede – 5’
Consciencialização Final</th></tr>
<tr><th colspan="2">Exercícios</th><th>Imagens</th><th>Critérios de êxito</th><th>Séries Reps / Veloc. Exec.</th></tr>
<tr><td>
</td><td>4. Flexibilidade activa das principais regiões musculares:
• Com ajuda da banda ou toalha
• OU Sem ajuda externa</td><td>• “Utilizar os músculos para mover os diferentes segmentos corporais
• A banda ou toalha são apenas auxiliares”!</td><td rowspan="2">Mobilizar activamente, com ou sem ajuda externa, as principais articulações envolvidas nas acções propostas:
• Coxo-femural, Joelho,Tornozelo;
• Ombro;
• Coluna.</td><td rowspan="2">• 1 série
• 4 – 6 ciclos respiratórios</td></tr>
<tr><td></td><td>5. “Cheklist” postural executada na fase inicial da aula - enfatizar a mobilidade e estabilidade da coluna, o alinhamento neutro associado a um correcto padrão respiratório</td><td>• “Utilizar os seus músculos para mover os diferentes segmentos corporais”
• “Sentir como os movimentos estão mais amplos e fáceis relativamente ao inicio da aula!”</td></tr>
<tr><td colspan="5">Orientações gerais:
7. O método utilizado para o treino da flexibilidade activa baseia-se na repetição do gesto por acção dos músculos agonistas, exigindo, simultaneamente, a estabilidade nos segmentos de apoio.
8. Tal como nas etapas anteriores, esta fase tem por objectivo promover no aluno a identificação das aprendizagens sobre o seu corpo conseguidas em cada sessão de treino.</td></tr>
</table>

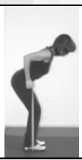
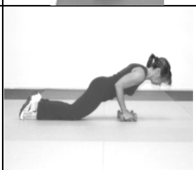
Período 3 – mesociclo 1

Período 3 - mesociclo 1

CIRCUITO UNÍSSONO

Aquecimento/cardio:

- mobilização articular pés, joelhos, bacia, tronco, ombro
- marcha estacionária com elevação de joelho (1 min contínuo x 3 séries) em estilo "piaffé"
- "sprints" e travagens ao sinal

Exercício			Alternativa	
1		Afundo dinâmico alternado (12-16 reps a 2x2)	Dinâmico com apoio das mãos	Unilateral com apoio das mãos
2		Remada baixa (12-16 reps 2x2)	Na parede	Na cadeira
Cardio: caminhar no meio dos obstáculos e desviar, ultrapassar, subir/descer (5 min)				
3		Agachamento a levantar e baixar um objecto (caixa, saco com areia, bola medicinal, etc.)	Agachamento sem carga	Sentar e levantar da cadeira
4		Push-up no chão a terminar com prancha de braços (8 reps 2x2 + 32T em prancha)	Idem no step	Na parede
Equilíbrio: Mudanças de plano: pé – 4 apoios – lateral – deitado, e caminho inverso				
5		Prancha de antebraços no chão (2 x 32T ou 4 x 16T)	No step ou cadeira	Na parede ou mesa ou step
6		Subir (rápido) e descer (lento) step ou degrau –15-20 reps com cada apoio (D/ E)	Calf raise unipedal com apoio na parede ou cadeira – 20-25 reps (D/E)	Calf raise com apoio na parede ou cadeira – 25-30 reps

Parte final

- Treino de estratégias posturais: "sempre em pé", quedas falsas (com ou sem ajuda), alcançar longe.
- Alongamentos dinâmicos com redução da base de apoio (apoio unido, apoio tandem, apoio unipedal) e alongamentos estáticos em duplas

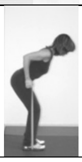
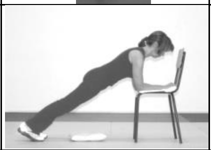
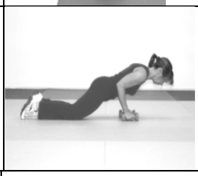
Período 3 – mesociclo 2

Período 3 - mesociclo 2

Aquecimento/cardio (10'):

- mobilização articular pés, joelhos, bacia, tronco, ombro
- caminhar no meio de obstáculos e desviar, ultrapassar, subir/descer (5 min)
- sprints e travagens ao sinal
- marcha estacionária com elevação de joelho (1 min x 3 séries) em estilo "piaffé"

Força funcional – planos de treino individuais (conforme página seguinte) **(20')**

1		Afundo dinâmico alternado
2		Remada baixa
3		Prancha de antebraços no chão
4		Agachamento a levantar e baixar um objecto
5		Push-up no chão a terminar com prancha de braços
6		Subir (rápido) e descer (lento) step

Parte final (10')

Equilíbrio:

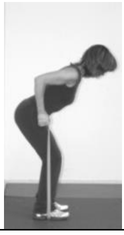
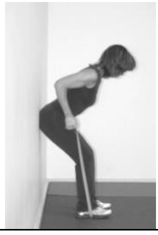
- Treino multisensorial - deslocamentos com: variações da superfície de apoio (colchões, esponjas, traves, etc.), tarefas cognitivas (fazer contas de cabeça, soletrar, palavras ao contrário), redução da visão (ler um texto, "apertar" os olhos, fechar um olho, reduzir iluminação), movimentação da cabeça;
- Estratégias posturais: "sempre em pé", quedas falsas, alcançar longe.

Alongamentos activos:

- Mudanças de plano: pé – 4 apoios – lateral – deitado, e caminho inverso
- Alongamentos dinâmicos com redução da base de apoio (apoio unido, apoio tandem, apoio unipedal) e alongamentos estáticos em duplas

Período 3 - mesociclo 2 - Prescrição Individual

Aluno: ________________________ *código:* ________ *idade:* ______ *turma:* ______________

Exercício				Reps	Series
① Afundo				16 x cada perna	2
② Remada				16 x	2
③ Prancha				3 x 10 seg	-
④ Push-up				8 a 12 x	2
⑤ Agachamento				16 a 20 x	2
⑥ Tornozelo				20 a 25 x	2

Período 3 – mesociclo 3

Período 3 - mesociclo 3 – Prescrição Autónoma

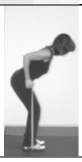
CIRCUITO POR ESTAÇÕES

Aquecimento/cardio (10'):

- mobilização articular pés, joelhos, bacia, tronco, ombro
- caminhar no meio de obstáculos e desviar, ultrapassar, subir/descer (5 min)
- sprints e travagens ao sinal
- marcha estacionária com elevação de joelho (1 min x 3 séries) em estilo "piaffé"

Força funcional – circuito A (máximo 10')

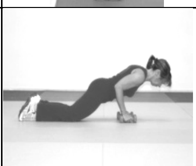
30 a 45s cada estação (2 séries) + 30s transição entre estações e séries

Estação		**Exercício**	**Alternativas**	
1		Afundo dinâmico alternado	Dinâmico com apoio das mãos	Unilateral com apoio das mãos
2		Remada baixa	Na parede	Na cadeira
3		Prancha de antebraços no chão	No step ou cadeira	Na parede ou mesa ou step

Estação de transição (5 min)

- Treino multisensorial - deslocamentos com: variações da superfície de apoio (colchões, esponjas, traves, etc.), tarefas cognitivas (fazer contas de cabeça, soletrar, palavras ao contrário), redução da visão (ler um texto, "apertar" os olhos, fechar um olho, reduzir iluminação), movimentação da cabeça;
- Estratégias posturais: "sempre em pé", quedas falsas, alcançar longe.
- Mudanças de plano: pé – 4 apoios – lateral – deitado, e caminho inverso

Força funcional – circuito B (máximo 10')

4		Agachamento a levantar e baixar um objecto (caixa, saco com areia, etc.)	Agachamento sem carga	Sentar e levantar da cadeira
5		Push-up no chão a terminar com prancha de braços (8 reps 2x2 + 32T em prancha)	Idem no step	Na parede
6		Subir (rápido) e descer (lento) step– 15s cada apoio (D/ E)	Calf raise unipedal com apoio	Calf raise com apoio

Parte final (5')

Alongamentos dinâmicos com redução da base de apoio (apoio unido, apoio tandem, apoio unipedal) e alongamentos estáticos em duplas