ESCOLA
SUPERIOR
DE SAÚDE
POLITÉCNICO
DO PORTO

P.PORTO

M

MESTRADO EM FISIOTERAPIA
ÁREA DE NEUROLOGIA

Association between the History of Fall and the Fear of Falling on stair descent and gait transition spatio-temporal parameters and lower limb kinetics and kinematics in older adults: an observational study.

Ivone da Silva Teles

07/**2023**

P.PORTO

ESCOLA
SUPERIOR
DE SAÚDE

Centro de Investigação em Reabilitação
Center for Rehabilitation Research

Association between the History of Fall and the Fear of Falling on stair descent and gait transition spatio-temporal parameters and lower limb kinetics and kinematics in older adults: an observational study.

Autor

Ivone da Silva Teles

Orientador(es)

PhD/Andreia Sousa / IPP-ESS

MSc/Juliana Moreira / IPP-ESS

PhD/Augusta Silva / IPP-ESS

Dissertação apresentada para cumprimento dos requisitos necessários à obtenção do grau de Mestre em **Fisioterapia** – Área de **Neurologia** pela Escola Superior de Saúde do Instituto Politécnico do Porto.

Acknowledgements

I would like to express my deepest appreciation to my advisors PhD Andreia Sousa, MSc Juliana Moreira and PhD Augusta Silva without whose guidance, availability, and most valued knowledge I would've not been able to finish this task.

I would like to extend my sincere gratitude to all the participants for their trust and willingness to cooperate in the study.

To my grandmother, who always worried if I was doing well, I wish I could tell her that it was worth it.

To my parents, my sister, and my brother, they're part of everything I do.

Resumo

Introdução: Estima-se que 20% das quedas nos adultos mais velhos ocorram em escadas, a maioria durante a descida na transição para a marcha. Embora a História e o Medo de Queda estejam relacionados com um risco de queda mais elevado, a sua associação com a alteração de parâmetros biomecânicos nesta tarefa funcional ainda não foi estabelecida.

Objetivo: Avaliar a associação entre a História e o Medo de Queda nos parâmetros espácio-temporais, cinéticos e cinemáticos do membro inferior em adultos mais velhos durante a descida de escadas e na transição para a marcha.

Métodos: Sessenta adultos mais velhos (>60 anos) foram avaliados com recurso a um sistema de captura de movimento optoeletrónico e duas plataformas de força durante a descida de escadas e na transição para a marcha. Foi utilizado para análise o valor médio da duração e velocidade da tarefa, duração do apoio único e duplo, pico de velocidade do centro de massa, ângulo, amplitude de movimento e potência da anca, joelho e tornozelo, *foot clearance* e *foot placement* através da análise multivariada da variância.

Resultados: O grupo FOF apresentou maior tempo de tarefa (p=0.009), de duplo apoio (p=0,047) e de apoio único (p=0,009) e menor pico de velocidade do centro de massa (p=0,043). No ciclo de escadas, o grupo FOF apresentou maior potência do tornozelo no *heel-strike* (p=0.026). No ciclo de marcha, o grupo HOF exibiu menor ângulo do tornozelo iniciante no *toe-off* (p=0.015), maior potência da anca iniciante no *heel-strike* (p=0,024) e do tornozelo contralateral no *toe-off* (p=0,029). O grupo FOF apresentou menor ângulo do tornozelo iniciante no *heel-strike* (p=0.041) e no *toe-off* (p=0.026) e no tornozelo contralateral no *toe-off* (p=0.022).

Conclusão: Nos adultos mais velhos, a História e o Medo de Queda estão associados a alterações de parâmetros biomecânicos na descida de escadas e transição para a marcha, consistentes com a adoção de estratégias mais conservadoras para evitar quedas.

Palavras – chave: história de queda; medo de queda; adultos mais velhos; descida de escadas; biomecânica.

Abstract

Background: It has been estimated that 20% of the falls in older adults occur on stairs, mostly during stair descent during gait transition. Although History of Fall and Fear of Falling are related to a higher risk of falling in older adults, their association with biomechanical changes in this functional task has yet to be established.

Purpose: To evaluate the association between History of Fall and Fear of Falling on spatio-temporal, lower limb kinetic and kinematic parameters in older adults during stair descent and gait transition.

Methods: Sixty older adults (>60 years) were evaluated through an optoelectrical motion capture system and two force plates during stair descent and gait transition. For the analysis it was used the mean value of the task velocity and time, single and double-support time, peak downwards center of mass velocity, hip, knee and ankle position, range of motion and power, foot clearance and foot placement, assessed using a multivariate analysis of variance.

Results: FOF exhibited longer task (p=0.009), double-support (p=0,047) and single-support (p=0,009) times and reduced peak downwards CoM velocity (p=0,043). In the stair cycle, FOF exhibited increased ankle power at heel-strike (p=0.026). In the gait cycle, HOF exhibited reduced initiating ankle angle at toe-off (p=0,015), increased initiating hip power at heel-strike (p=0,024) and contralateral ankle power at toe-off (p=0,029). FOF presented reduced initiating ankle angle at heel-strike (p=0.041) and toe-off (p=0.026) and reduced contralateral ankle angle at toe-off (p=0.022).

Conclusion: In older adults, History of Fall and Fear of Falling are associated with changes in biomechanical parameters during stair descent and gait transition, consistent with the use of more conservative strategies to avoid falling.

Keywords: history of fall; fear of falling; older adults; stair descent; biomechanics.

Table of Contents

List of Abbreviations

ACQ – Assessment and Characterization Questionnaire

ADL's – Activities of Daily Living

BI – Barthel Index

BMI – Body Mass Index

CI – Confidence Interval

CoM – Center of Mass

CoP – Center of Pressure

FC – Foot Clearance

FES-I – Fall Efficacy Scale – International

FoF – Fear of Falling

FP – Foot Placement

FRID's – Fall-Risk Increasing Drugs

FTSTS – Five Times Sit-To-Stand

HGS – Hand Grip Strength

HoF – History of Fall

HS – Heel-Strike

ICC – Intraclass Correlation Coefficient

IPAQ – International Physical Activity Questionnaire

Lawton IADL – Lawton and Brody Instrumental Activities of Daily Living Scale

MANOVA – Multivariate Analysis of Variance

MMSE – Mini-Mental State Examination

PA – Physical Activity

ROM – Range of Motion

STROBE – Strengthening the Reporting of Observational Studies in Epidemiology

TO – Toe-Off

TUG – Timed-Up-and-Go

UE – European Union

WHO – World Health Organization

List of Tables

List of Figures

Introduction

The 21st century runs its course towards an aged society rather than an aging one, with more than 1 billion people aged over 60 years (1). The World Health Organization (WHO) projected that between 2010 and 2050, at a global level, older adults would be the population with the highest growth rate (2). The aging process is, therefore, one of the main concerns of our time, so much so, that the United Nations has declared the period between 2021 and 2030 as the "Decade of Healthy Aging" (1). Portugal follows this tendency, given that the most recent "Eurostat" data puts it as the fourth European Union (UE) country with the highest percentage of older adults, with 22,4% of people aged over 65 in 2020, more than the UE mean, which was 20,8% (3). In 2021, the most recent Portuguese census data, found a 23,4% increase in the elderly population and a 12,9% decrease in the young population (4). By 2021, the population aging ratio had grown from 128 elderly people per 100 young people to 182 elderly people per 100 young people (4), expected to rise from 2,2 to 3,0 million by 2080 (5).

The aging process causes systemic changes at functional and structural levels (6), generally manifesting itself in deficits in cardiorespiratory function (7), slowness, strength loss, reduced flexibility, weight loss, decreased ability to perform activities of daily living (ADL's), and fatigue (8, 9). There are also physiological alterations, such as, stiffening of periarticular soft tissues that cause joint constraint (10), which reduces lower limb range of motion (ROM) (11) and cognitive impairments when it comes to learning, decision-making, memory, and attention (12). Specifically, in the central nervous system, there are neuroanatomical, neurotransmission, and neurophysiological alterations such as reduced blood flow, cerebral atrophy, reduced neuron counting and a decrease in both cholinergic transmissions and dopamine synthesis (12). In the neuromuscular system there's a decrease in reflexes, automated rhythmic and voluntary movements (11), and muscle activation alterations (8) which lead to a deficit in the optimal production of motor response and control (13). There is also an impairment in the ability of the nervous system to process vestibular, visual and proprioceptive input which impairs the postural control mechanisms (10, 12). Aging also results in altered neuronal networks connectivity, motor neuron degeneration (14), reduced gray matter volume related to gait disturbances and white matter hyperintensity associated with mobility limitation (15).

From a biomechanical perspective, aging affects spatio-temporal, kinematic, and kinetic parameters (17). It has been established that, in older adults, the decrease in gait velocity declines 1% per year from the age of 60 years (16, 18). Furthermore, older adults have exhibited a cadence, step and stride length reduction, as well as, a greater base of support and variability on single and double-support time (17-19). A reduction in single-support time in older adults may be the result of deficits in swing limb advancement, as well as, muscle power deficits (18). The increase in double-support time could be related to the decrease in the stability of the trunk and lower limbs (18). An association between aging and a greater center of pressure (CoP) variability has also been established (17). This is significant because CoP represents the neuromuscular response that controls the center of mass (CoM) movement in order to maintain forward progression and upright balance (17). An inability to simultaneously increase the vertical and forward components of the CoM velocity (20) has also been reported. Focusing on lower limb performance previous literature has reported reductions in the hip, knee and ankle ROM and power (18, 21), related to joint flexibility deficits or joint stiffening causing co-contractions of antagonist muscles (21, 22). Older adults experience exacerbated declines in biomechanical parameters which can be an early sign of their functional worsening and risk of falling (18).

As a matter of fact, risk of falling and the increase in fall incidence in older adults are among the main concerns of the current times, given their exponential growth (24). Even more so, falls are the main cause of injury, accounting for 45% of deaths in older adults (25). It has been estimated that one third of the community-dwelling population aged over 60 years experiences at least one fall per year (24, 25). The incidence increases as people get older, reaching 32% to 42% in the population aged over 70 years (28). Not only the History of Fall (HoF) but also the Fear of Falling (FoF) have been shown to have a high association with risk of falling (27, 28). HoF, specifically, a recent one, consists of a prominent risk factor for subsequent falls in community-dwelling older adults (31). FoF is considered a significant predictor of the occurrence of falls in community-dwelling older adults (32), with a prevalence of 20% to 39% among this population (28, 31). The concept of FoF has evolved from the mere fearful anticipation of falling to also include decreased self-efficacy or confidence in one's balance and/or activity and participation avoidance (33). Although approximately one-half of older adults who fall develop FoF, it can also be present in people who have not fallen (30).

Within the falls framework, it has been estimated that 20% occur on stairs (34), from those, 75% occur while descending stairs (33, 34, 35) making it a three times more dangerous activity than stair ascent and ten times more dangerous than walking (38). Stair descent is considered one of the most demanding ADL's by older adults (36) and has become one of the main concerns of the scientific community, given that, when compared to falls during walking there is a much higher risk of mortality and serious injuries (23). The mechanisms behind falling during stair descent are multifactorial, either intrinsic, like PA, functionality, strength and flexibility decline and/or sensorimotor, postural, and motor control deficits or extrinsic like the environmental conditions, such as, presence of obstacles (24, 37, 38). Stair descent imposes a higher neuromuscular and sensorimotor demand for controlling the CoM when stepping down (36, 39), there is a single-support period associated with the lowering of the CoM while the contralateral limb reaches forwards and downwards in order to make contact with the step below (42). Older adults have more difficulty controlling fast vertical displacements of the CoM (41, 42) and display reduced anteroposterior and mediolateral balance control, which predisposes them to a higher risk of falls (38). Older adults adopt alternative strategies in order to limit the downwards velocity of their CoM during the lowering phase of descent (43, 44). They often exhibit decreased descent velocity and single-support time (40, 43), increased double-support time (18) and foot placement (FP) (43) and reduced foot clearance (FC) (37). Stair descent requires lower limb joints to undergo larger ROM (34, 45) and the high levels of joint power demand leave little reserve capacity to cope with unexpected disturbances, which could also explain the high prevalence of stair descent falls in older adults (42). These usually happen near the bottom of the staircase, close to the transition to gait, when older adults tread on the last step thinking the ground has been reached (37). Furthermore, when older adults transition to gait after descending the stairs, the nervous system must quickly respond to a change in the motor task, this ability may be less efficient due to age, putting them at a higher risk of falling during this moment (48). Reduced gait velocity, lower limb ROM and ankle position and power are the most consistent findings among older adults (10, 11, 29, 49, 50, 51). However, regarding the downwards CoM velocity even though some authors have reported a decrease in older adults (42, 45, 46), there's also a few studies that reported that due to their inefficiency in generating braking forces and in controlling CoM vertical displacements, older adults contact the step below with higher CoM velocity (41, 52). Regarding joint power, there's still no consensus on the hip compensation for the reduction in ankle power generation (53). The aforementioned changes have previously been consistently associated with aging, however, a sustained association with HoF or FoF has yet to be established.

Given that stair descent is related to a higher incidence of falls and worst consequences in older adults and is essential to the independence and quality of life of this population, the study of solutions that are able to predict incapacity becomes imperative in order to prevent the occurrence of falls. There's research available demonstrating the influence of age on stair descent in older adults, however, the integration of spatio-temporal parameters with lower limb kinematics and kinetics has only been performed by few studies (33, 39, 42, 43, 47) and few authors have focused on both stair descent and gait transition (34, 39, 42, 48). To the extent of our knowledge there's no research available that analyzes the association between HoF and FoF on these parameters during stair descent and gait transition. Therefore, the aim of this study is to evaluate the association between HoF and FoF on spatio-temporal parameters and lower limb kinetic and kinematic parameters in older adults during stair descent and gait transition. Specifically, spatio-temporal parameters will be assessed through task velocity and time, single and double-support time and peak downwards CoM velocity, kinematic data will be assessed through hip, knee and ankle position and ROM, FC and FP, while kinetics will be assessed through joint power.

Materials and Methods

Study Design

According to Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) (56), a cross-sectional study was designed and implemented.

Participants

Participants were considered eligible if they were community-dwelling healthy cooperative subjects aged 60 years or older and able to independently perform ADL's and descend stairs. The exclusion criteria included having an established diagnosis of malignancy or terminal diseases with an anticipated survival prognosis of less than a year, suffer from diabetic foot, lower limb fracture in the previous 6 weeks or other related conditions, being in recovery from an acute illness or injury, neurological, musculoskeletal, cognitive, cerebrovascular, and respiratory conditions, and/or sensorimotor, visual, vestibular, hearing deficits that prevent the subject from understanding the task, centrally acting medication that may affect movement and/or postural control, and the presence of pain that might impair the task. Participants responded to the sample selection questionnaire, and if the eligibility criteria were met and the subjects accepted to enroll in the study, they were contacted to schedule the assessment (see Figure 1). In the assessment moment, the participants responded to the "Assessment and Characterization Questionnaire (ACQ)", which included several characterization questions and structured questionnaires that allowed us to allocate them according to their HoF and FoF.

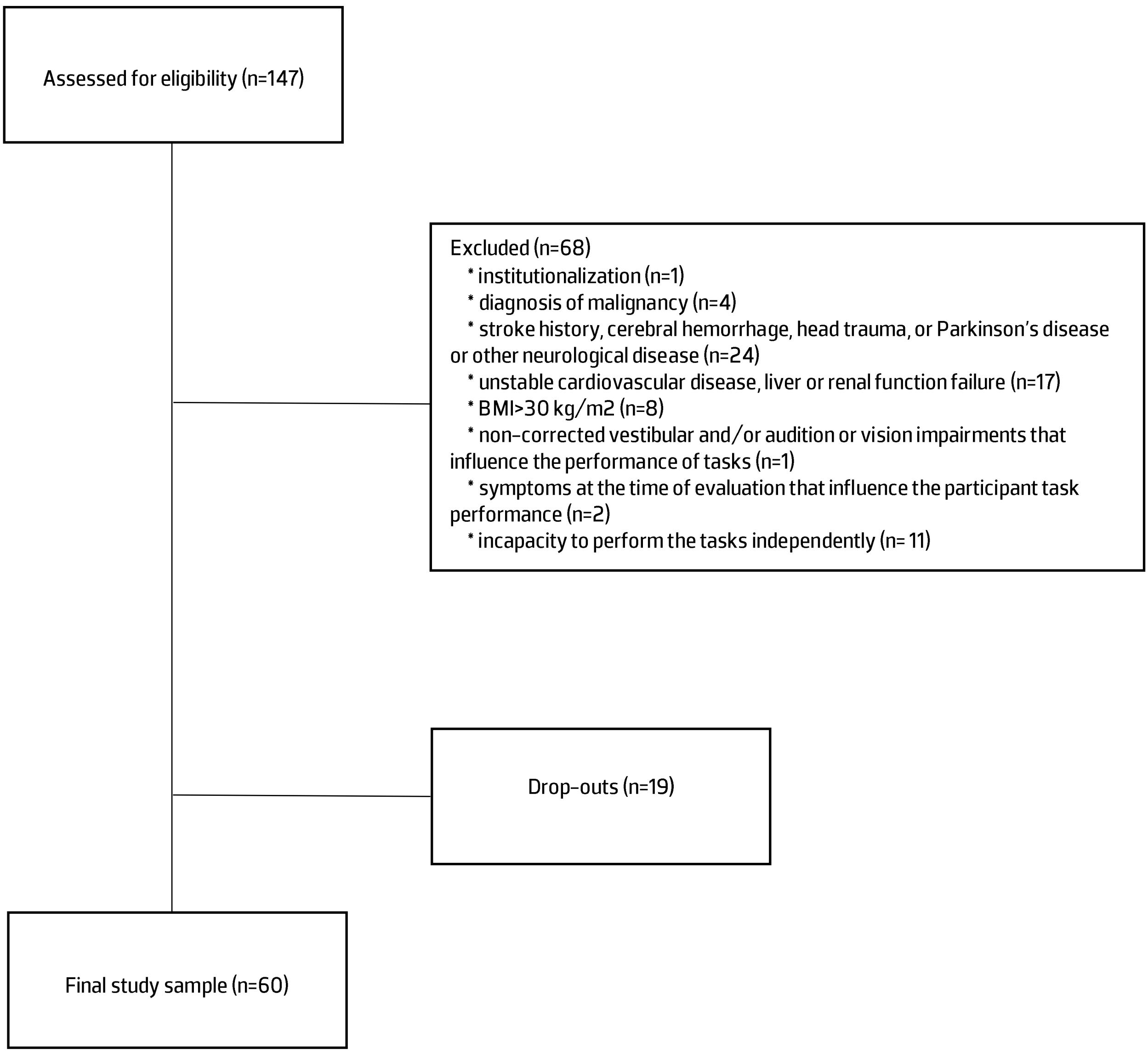


Figure 1 – Flowchart of the sample selection.

Ethical Considerations

All participants were informed about the purpose of the study and its protocol and signed an informed consent form. On the 27th of April of 2022, the study was submitted to the Institutional Ethics Committee and received approval on the 25th of May 2022, after an evaluation that stated that the use of personal data would follow UE regulations 2016/679 and Portuguese regulations 58/2019. The confidentiality was assured through the investigator assigning a code to the participants data that was available on a computer protected by a password only known to the investigator. Ethics Committee Registration Number: CE0064C.

Instruments

The ACQ consists of seven questions concerning the subject's anthropometric characteristics, Body Mass Index (BMI), health conditions, prescribed medication and fall assessment (47, 48). HoF was assessed through the dichotomous "yes or no" question: "Have you suffered a fall in the previous 12 months?" (48, 49). This single-item question was associated with increased positive likelihood odds of falling with a odds ratio 4.2 higher than "American Geriatric/ British Geriatric Screening Questions", specificity accompanied the "Short Fall Efficacy Scale – International (short FES-I)" with its sensitivity being higher among those aged over 85 (60). FoF assessment consisted of the dichotomous "yes or no" question: "Are you afraid of falling?" (61). This single-item question reliability and criterion validity have been demonstrated in community-dwelling older adults (62), presenting a good test–retest reliability (0.66) and correlation of 0.723 with the FES–I (63).

The "Portuguese Version of Mini-Mental State Examination (MMSE)" consists of a brief and quantitative measure that provides a quantity estimation of the severity of cognitive impairment and documentation of its changes overtime (64). The MMSE is one of the most widely used screening tests to detect cognitive impairment in older adults (65) and was adapted and validated for the Portuguese population (66). The MMSE has been shown to have both good test-retest reliability (0.80–0.95) (65) and excellent inter-rater reliability (intraclass correlation coefficient (ICC): 1.00, 95%; confidence interval (CI): 1.00 - 1.00) (67). Its diagnostic acuity based on the most recent normative data revealed an overall excellent specificity (superior to 90%) (68) and acceptable sensitivity to detect mild to moderate stages of dementia (65).

The "International Physical Activity Questionnaire (IPAQ)" is a self-reported questionnaire for assessing PA (69) covering four domains of PA (leisure time, domestic activities, work and transport-related) and four types of PA (sitting, walking, moderate and vigorous-intensity activities) (70). It was developed to establish a standardized and culturally adaptable measurement tool for assessing PA in different areas of the world and, accordingly, it has been validated in 12 countries (59, 60). It has been adapted and validated for the Portuguese population (71) and, more specifically, for the assessment of PA in older Portuguese adults (62, 63). The reliability of the IPAQ has been found to be moderate to high (rw: 0.40 to 0.74) (70) and to have produced repeatable data (Spearman's clustered around

0.8), indicating very good repeatability (71). Criterion validity has been shown to consist of a median of 0.30, which was comparable to most other self-report validation studies (71).

The "Barthel Index (BI)" is an ordinal scale used to measure performance in ADL's, ten variables describing ADL's and mobility are scored (from 0 to 100), depending on the time taken and physical assistance required to perform each item (74). A higher score reflects a greater ability to function independently (74-76). It was adapted and validated for the Portuguese population (75) and has been shown to be suitable to measure changes in physical function of older individuals, with sufficient inter-rater reliability (ICC of 0.96; 95% CI 0.93-0.98) (76).

The "Lawton and Brody Instrumental Activities of Daily Living Scale (Lawton IADL)" is intended to be used among community-dwelling older adults and is an appropriate instrument to assess independent living skills considered more complex than the basic ADL´s (77). The Lawton IADL is most useful to identify how a person is functioning at the present time, and to identify improvement or deterioration over time (77). It was adapted and validated for community-dwelling Portuguese older adults (78), and it has since been used to assess their performance in ADL's (69, 70). Inter-rater reliability was established at 0.85 and the validity was estimated by determining the correlation of the Lawton IADL with four scales, in which all correlations were significant at the 0.01 or 0.05 level (81).

"Hand Grip Strength (HGS)" is recognized as a surrogate measure of whole-body strength and can be used to assess age-related deterioration in function and health status (82) being recommended by the "American Society of Hand Therapists" (83). Among older adults, decreased HGS is associated with greater risk of frailty, loss of physical function, mobility and overall muscular strength and power (82). HGS values have been established for the Portuguese population aged 65 years or older. (84). The reliability studies showed that HGS is a reliable method (ICC values 0.85–0.98), the intra-tester reliability shown that the ICC varied between 0.94 and 0.98 (85), furthermore, excellent concurrent validity has also been reported (Pearson r: 0.9998; r > 0.96) (86).

The "Five Times Sit-To-Stand (FTSTS)" is a highly reliable tool for assessing lower limb strength, dynamic balance and functional mobility (87), with significant predictive value for recurrent falls in community-dwelling older adults (88). Its normative values, reliability and validity have been well described in healthy older community-dwelling individuals (89). It has excellent intra-rater reliability (ICC range: 0.914–0.933) and test-retest reliability (ICC range: 0.988–0.995) in healthy older adults (90). It was estimated as a valid measure when compared to the "Timed-Up-and-Go (TUG)" test (Pearson r: 0.64, p<0.001) (91).

TUG is clinically applicable and reliable across multiple populations, regardless of age (92). It assures content validity by evaluating well recognized ADL's, and concurrent validity, by correlating well with measures of balance, gait velocity and functional abilities (93, 94). Intratester (ICC: 0.92) and intertester (ICC: 0.99) reliability have been reported to be high in older adults and moderate in the community-dwelling ones (ICC: 0.56) (95). Its validity has been shown by correlating scores with gait speed (Pearson r: 0.75), postural sway (Pearson r: -0.48), step length (Pearson r: -0.74), "BI" (Pearson r: -0.79), and step frequency (Pearson r: -0.59) (95).

Testing Protocol

The experiment was conducted at the Center for Rehabilitation Research of School of Health, Polytechnic of Porto. The session began with the "vital signs before assessment" evaluation followed by the demographic and anthropometric data collection. Participants answered the ACQ, the IPAQ, the MMSE, the BI and the Lawton IADL. Afterwards, body composition data was collected through "Bioelectrical Impedance", followed by the HGS test. Participants were assessed on their functional ability through the FTSTS and TUG. Prior to the data collection, a total of 82 reflective markers were attached to anatomical landmarks according to the guidelines (96, 97, 98, 99). Participants were monitored with an optoelectronic system while performing the FTSTS, the TUG, stair descent and gait transition.

Accordingly, kinematic and kinetic data was collected synchronously, using the Qualisys Track Manager (Qualisys AB®, Sweden) with thirteen optoelectronic cameras (eight Oquos500, four MiqusM3), one Miqus video camera and two force plates (FP4060-08/10, Bertec®), using a marker setup adapted from the collaboration between Istituto Ortopedico Rizzoli and other authors (96-98) adding the head segment (C-Motion, Inc., EUA) and Rab Upper Extremity Model (99).

A three-step staircase (step height: 16cm, tread depth: 29cm and step width: 69cm) was used to perform the stair descent (see Figure 2) (33, 42, 90). All participants were instructed to start at the top of the staircase from an upright position with feet side by side (39, 40) and to descend the staircase at their own self-selected initiating limb and velocity (36, 43, 91). They were also instructed to continue walking for at least two steps once they reached level ground (44). A trial finished once the participants came to a stationary standing position on level ground (42). Handrails were present throughout the trials as a safety precaution, however, participants were instructed not to use them unless necessary and no trials were recorded if handrails were used (32, 91). For safety reasons, there was also an investigator next to the staircase accompanying the descent (38). All participants performed a stair descent practice trial before the experimental trial to enhance their familiarity with the protocol (42, 90). The protocol consisted of three completed trials per participant (32, 36). At the end of the third trial "vital signs after assessment" were evaluated.

Data Processing

Data processing was wielded both on previous software as in the Visual3D Professional (v.6.01.36, C-Motion, Inc., USA), or others if needed. Anthropometric measurements from each participant were entered into the model and the data was exported into Visual3D Professional (v.6.01.36, C-Motion, Inc., USA) (54) (42). A static calibration trial was collected prior to the movement trials to define segment lengths and identify lower limb joint centers

(35). Accordingly, the stair descent mechanics of the participants were described with reference to a neutral upright position that each participant performed before measurement (39, 40).

Data from the stair descent and gait transition of three trials per participant was collected for the purpose of this study, therefore, for the data collection facilitation the topmost step of the staircase was labeled "Step 4", and the subsequent steps were labeled as "Step 3", "Step 2" and "Step 1" (see Figure 2) (35). The only stair descent data selected for further analysis was extracted from the stair cycle and the gait transition data from the gait cycle on level ground (35). The stair cycle initiated at the moment of the initiating limb heel-strike (HS) on "Step 2" and finished with the initiating limb HS on the level ground (see Figure 3) (54). The gait cycle initiated with the moment of the initiating limb HS on the level ground and finished with the following initiating limb HS (20). The moment of toe-off (TO) was defined by the maximum heel marker's vertical velocity, and the moment of HS was defined by the minimum downwards CoM velocity (45).

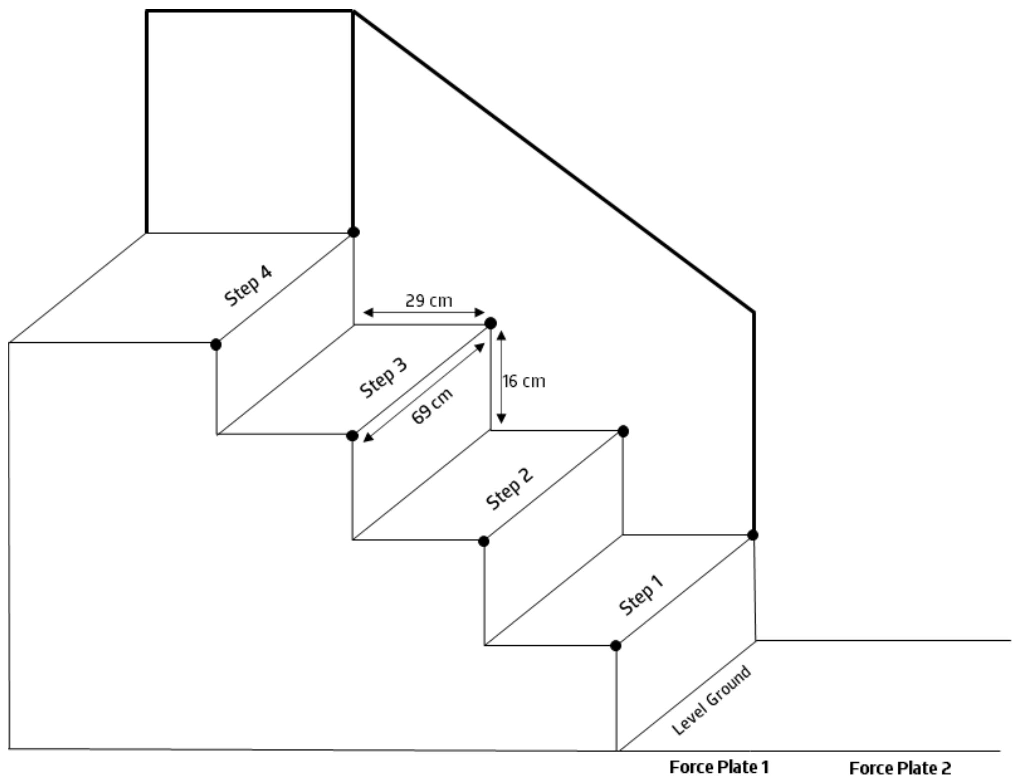


Figure 2 - Schematic representing the staircase characteristics.

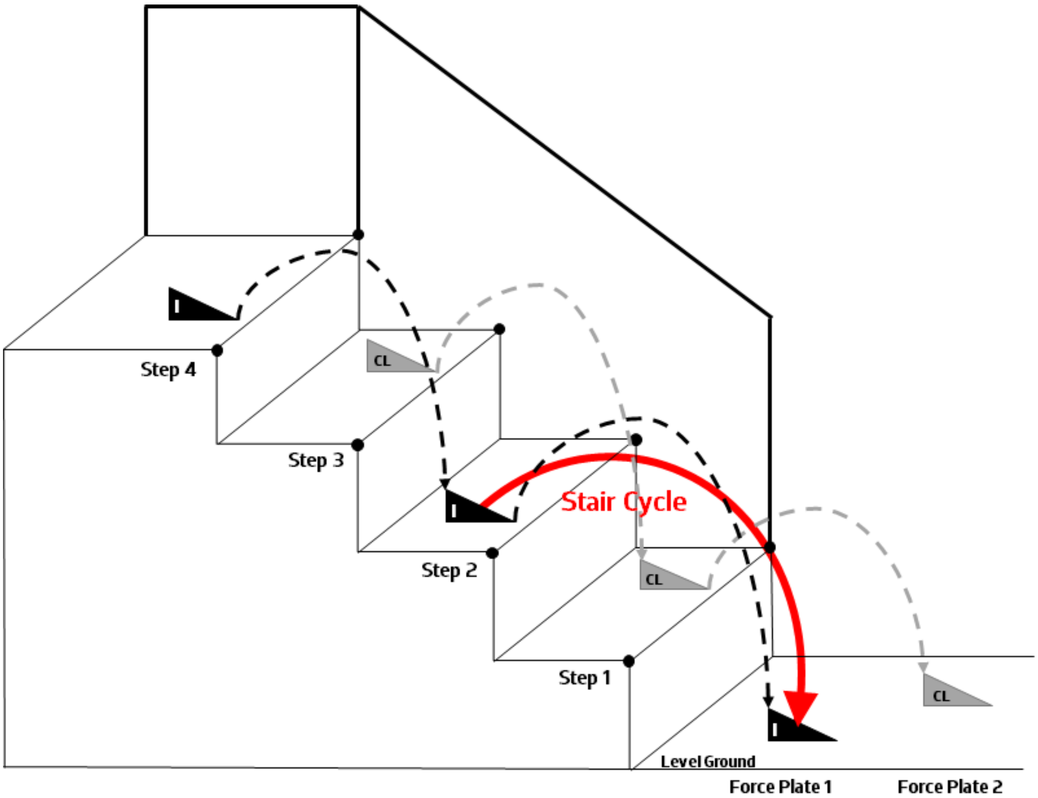


Figure 3 – Schematic demonstrating the initiating limb (I – in black) and contralateral limb (CL – in grey) trajectories during the stair descent. The red arrow represents the stair cycle, starting with the initiating limb on step 2 and terminating with the initiating limb on level ground. The triangle on the step represents the stance phase and the dashed line represents the swing phase. The only stair descent data for further analysis was extracted from the stair cycle.

Extracted spatio-temporal parameters included task velocity (m/s) and time (s), single and double-support time (s) (35) and peak downwards CoM velocity (m/s) (100). In the stair cycle, the lower limb kinematics were characterized by FC and FP, hip, knee and ankle angles at the moment of FC and FP, maximum and minimum angles and ROM of both limbs (41). In the gait cycle, the lower limb kinematics were characterized by the initiating and contralateral hip, knee and ankle angles at HS and TO (8). In the stair cycle, hip, knee and ankle vertical joint power was extracted at the initiating limb HS when it reached level ground (35). In the gait cycle, hip, knee and ankle sagittal joint power was extracted from the HS and TO of both limbs on level ground (36). A Lowpass filter from Butterwoth class with a cut-off frequency of 6.0Hz was used on the joint angles and joint power variables. Joint power was calculated as the product of the joint moment and joint velocity ((Power= Mx.wx + My.wy + Mz.wz), M– joint moment; w – joint angular velocity) (45). Their profiles for the hip, knee and ankle were summed to yield the support moment (positive for flexion, negative for extension) and combined joints power (positive for power generation, negative for power absorption), respectively (45). Reference frame was set as positive z-axis directed vertically up, positive y-axis directed in the direction of motion, and positive x-axis directed from left to right (x: flexion/extension, y: abduction/adduction and z: longitudinal rotation) (35). Segmental CoM location was obtained from the body segment parameter data and the position of the whole body CoM was estimated as the weighted sum of the various body segments using Visual3D (v.6.01.36, C-Motion, Inc., USA) (101). FC was established as the minimum resultant horizontal distance between the step-edge and the heel at the instant the heel passed the vertical height of the step-edge (43). For the initiating limb FC data was extracted from the instant the heel passed the vertical height of the Step 1. For the contralateral limb, FC data was extracted from the instant the heel passed the vertical height of the Step 2. FP was measured as the horizontal distance between the step-edge and the calcaneus at the instant of the initial foot contact (43). For the initiating limb FP data was extracted from the instant of the initial foot contact on Step 2. For the contralateral limb, FP data was extracted from the initial foot contact on Step 1.

Statistical Analysis

The sample size calculation was conducted through the "G*Power 3.1.9.7" statistical software. By having an estimation of the statistical power, the significance level and the expected effect size, through the difference between two independent means T test, it was possible to establish an "A priori sample size calculation" that determined the minimum value required to minimize the publication bias of the current study (102). Using the purpose of detecting differences on the "Hip angle at TO" of older adults during stair descent of Marques et al., (2013), it was possible to estimate an "effect size of d" of 0.8631101 for a "α err prob" of 0.05 and a "power" of 0.8. The result of the sample size calculation was 23 participants in each group with a total sample size of 46. When a study regards falls on older adults it is possible not to have groups with the same N, as long as, around 30% of the participants present HoF, since, it has been consistently estimated by previous literature that the prevalence of falls in this population stands at 30% (13, 24, 25, 27, 103, 104).

For the statistical analysis, the data consisting of the mean values of the three trials of each participant (41) was exported into the "IBM SPSS STATISTICS" v28.0.0.0 (190) (SPSS Inc., Chicago, IL, USA) (54). The data was assessed for the normality of the distribution, given that the NHOF and NFOF group had a N>30 it was assumed that its data followed a normal distribution (105). On the contrary, the normality of the distribution of the HOF and FOF groups were assessed through the Shapiro-Wilk test (105). A mixed-design multivariate analysis of variance (MANOVA) with the HOF and FOF as fixed factors and the characteristics, spatio-temporal, kinematic and kinetic parameters as dependent variables, was used to determine the main and interaction effects for each of the parameters, in compliance with the MANOVA assumptions verified through multivariate normality, probability sampling method, equal variance and absence of multivariate outliers (106). The categorical variables were analyzed through the Pearson's chi square test (107) and the Fisher's Exact test (108). The level of significance was set at $p \leq 0{,}05$ (109).

Results

A total of 60 participants enrolled in the study (see Figure 1), the descriptive statistics of their characteristics are summarized in the Table 1. Older adults with HoF presented a significantly higher number of prescribed medication when compared to older adults without HoF (p=0.018). On the contrary, regarding MMSE, the HOF group scored significantly lower than the NHOF group (p=0,014). Older adults with FoF presented a significantly higher BMI when compared to older adults without FoF (p=0.037). On the contrary, regarding BI, the FOF group scored significantly lower than the NFOF (p≤0.001). There was no interaction between HoF and FoF for any dependent variable.

Table 1 – Baseline participant characteristics mean (± SD) differences in older adults with (HOF) and without history of fall (NHOF) and with (FOF) and without fear of falling (NFOF).

Characteristics	NHOF (n=38)	HOF (n=22)	NFOF (n=41)	FOF (n=19)	Between Subjects Comparisons p value (observed power)		
					HOF	***FOF***	***HOF*FOF***
Age (y)	66,34 ±5,11	68,91 ±7,51	66,68 ±6,47	68,58 ±5,37	0,228 (0,224)	0,421 (0,125)	0,691 (0,068)
Gender							
Men	17(44,7%)	5(22,7%)	18(43,9%)	4(21,1%)	0,104[b]	0,149[b]	–
Women	21(55,3%)	17(77,3%)	23(56,1%)	15(78,9%)			
Height (m)	1,63 ±0,08	1,57 ±0,07	1,62 ±0,08	1,58 ±0,07	0,061 (0,468)	0,151 (0,299)	0,347 (0,154)
Weight (kg)	67,92 ±10,20	63,01 ±9,45	65,92 ±10,56	66,54 ±9,40	0,114 (0,352)	0,557 (0,089)	0,557 (0,089)
Body Mass Index (kg/m²)	25,68 ±3,11	25,34 ±2,59	25,03 ±2,84	26,67 ±2,83	0,496 (0,103)	**0,037 (0,558)**	0,899 (0,052)
Health Condition							
Yes	29(76,3%)	17(77,3%)	31(75,6%)	15(78,9%)	0,597[a]	0,526[a]	–
No	9(23,7%)	5(22,7%)	10(24,4%)	4(21,1%)			
Number of Health Conditions	1,61 ±1,26	1,45 ±1,10	1,39 ±1,13	1,89 ±1,29	0,268 (0,196)	0,173 (0,273)	0,158 (0,290)
Medication							
Yes	32(84,2%)	21(95,5%)	35(85,4%)	18(94,7%)	0,246[a]	0,414[a]	–
No	6(15,8%)	1(4,5%)	6(14,6%)	1(5,3%)			
Number of Medication	2.42 ±2,06	4,14 ±2,59	2.88 ±2,42	3,42 ±2,36	**0,018 (0,666)**	0,720 (0,065)	0,672 (0,070)
History of Fall							
Yes	0	100%	13(31,7%)	9(47,4%)	–	0,264[a]	–
No	100%	0	28(68,3%)	10(52,6%)			
Number of Falls	0	1,50 ±0,86	0,44 ±0,74	0,79 ±1,13			
Fear of Fall							
Yes	10(26,3%)	12(54,5%)	0	100%	0,104[b]	–	–
No	28(73,7%)	10(45,5%)	100%	0			
Mini-Mental State Examination	29,16 ±1,27	28,27 ±1,42	28,95 ±1,43	28,58 ±1,26	**0,014 (0,701)**	0,437 (0,120)	0,355 (0,151)
IPAQ (MET-min/week)	3279,78 ±2857,65	3403,91 ±3002,25	3426,68 ±3047,40	3106,50 ±2569,57	0,653 (0,073)	0,776 (0,059)	0,429 (0,123)
Barthel Index	19,92 ±0,27	19,82 ±0,40	20 ±0,00	19,63 ±0,50	0,365 (0,146)	**0,000 (0,996)**	0,365 (0,146)
Lawton IADL	22,42 ±2,19	22,82 ±0,66	22,54 ±2,10	22,63 ±0,83	0,607 (0,080)	0,949 (0,050)	0,429 (0,123)
Hand Grip Strength	29,57 ±8,00	25,00 ±9,00	29,09 ±9,28	25,30 ±6,35	0,067 (0,451)	0,167 (0,280)	0,634 (0,076)
Five Times Sit to Stand	15,27 ±3,68	15,84 ±3,82	15,26 ±3,78	15,95 ±3,60	0,983 (0,050)	0,726 (0,064)	0,165 (0,283)
Timed Up and Go	9,03 ±1,81	9,81 ±2,22	9,16 ±2,03	9,65 ±1,90	0,173(0,274)	0,481 (0,107)	0,754 (0,061)

[a] *Pearson's chi-squared Test*
[b] *Fisher's Exact Test*

Spatio-temporal parameters

The task's spatio-temporal descriptive statistics are summarized in Table 2. Older adults with FoF exhibited significantly longer task (p=0.009), double-support (p=0,047) and single-support (p=0,009) times when compared to older adults without FoF. On the contrary, the FOF group showed significantly reduced peak downwards CoM velocity than the NFOF group (p=0,043). There was no interaction between HoF and FoF for any dependent variable.

Table 2 – Task's spatio-temporal parameters group mean (± SD) differences in older adults with (HOF) and without history of fall (NHOF) and with (FOF) and without fear of falling (NFOF) when descending steps two and one, reaching level ground and walking two steps forward.

Spatio-Temporal Parameters	NHOF (n=38)	HOF (n=22)	NFOF (n=41)	FOF (n=19)	Between Subjects Comparisons p value (observed power)		
					HOF	*FOF*	*HOF*FOF*
Task Velocity (m/s)	0,87 ±0,15	0,81 ±0,28	0,88 ±0,22	0,79 ±0,16	0,488 (0,106)	0,257 (0,203)	0,417 (0,127)
Task Time (s)	1,13 ±0,18	1,18 ±0,25	1,09 ±0,18	1,26 ±0,22	0,689 (0,068)	**0,009 (0,764)**	0,586 (0,084)
Double-Support Time (s)	0,28 ±0,06	0,28 ±0,09	0,26 ±0,06	0,30 ±0,09	0,705 (0,066)	**0,047 (0,513)**	0,873 (0,053)
Single-Support Time (s)	0,70 ±0,11	0,71 ±0,16	0,68 ±0,11	0,77 ±0,14	0,710 (0,066)	**0,009 (0,755)**	0,476 (0,109)
Peak downwards CoM Velocity (m/s)	-0,54 ±0,09	-0,49 ±0,14	-0,54 ±0,11	-0,47 ±0,11	0,287 (0,185)	**0,043 (0,530)**	0,668 (0,071)

Stair cycle kinematic and kinetic parameters

The kinematic and kinetic descriptive statistics of the stair cycle are summarized in Table 3 and 4, respectively.

Regarding lower limb kinematics, there's a tendency towards existing statistically significant differences between older adults with and without FoF in the initiating FC and the contralateral hip angle at the moment of FP, both were reduced in the FOF group when compared to the NFOF group.

Regarding lower limb kinetics, older adults with FoF exhibited significantly increased ankle joint power at HS when compared to older adults without FoF (p=0.026). There was a tendency towards existing statistically significant differences between older adults with and without FoF in the initiating knee joint power at HS, the aforementioned was increased in the FOF group when compared to the NFOF group.

Table 3 – Step cycle kinematic parameters group mean (± SD) differences in older adults with (HOF) and without history of fall (NHOF) and with (FOF) and without fear of falling (NFOF) when descending steps two and one and reaching level ground.

Stair Cycle Kinematics	Limb	**NHOF (n=38)**	**HOF (n=22)**	**NFOF (n=41)**	**FOF (n=19)**	Between Subjects Comparisons p value (observed power)		
						HOF	***FOF***	***HOF*FOF***
Foot Placement (m)	Initiating	0,20 ±0,01	0,20 ±0,02	0,20 ±0,01	0,20 ±0,01	0,855 (0,054)	0,882 (0,052)	0,622 (0,078)
	Contralateral	0,19 ±0,01	0,19 ±0,02	0,19 ±0,01	0,20 ±0,02	0,594 (0,082)	0,349 (0,153)	0,644 (0,074)
Foot Clearance (m)	Initiating	0,19 ±0,04	0,20 ±0,03	0,20 ±0,04	0,19 ±0,04	0,747 (0,062)	0,066 (0,453)	0,074 (0,432)
	Contralateral	0,06 ±0,01	0,06 ±0,02	0,06 ±0,01	0,06 ±0,01	0,282 (0,187)	0,884 (0,052)	0,385 (0,138)
Hip Angle (degrees)								
At Foot Placement	Initiating	29,38 ±10,99	29,41 ±10,73	29,28 ±11,49	29,60 ±9,44	0,877 (0,053)	0,984 (0,050)	0,623 (0,077)
	Contralateral	28,47 ±10,56	31,66 ±10,60	31,07 ±10,18	26,56 ±11,10	0,272 (0,194)	0,071 (0,441)	0,485 (0,106)
At Foot Clearance	Initiating	32,67 ±10,84	32,20 ±10,83	31,72 ±10,92	34,17 ±10,46	0,687 (0,068)	0,451 (0,116)	0,665 (0,071)
	Contralateral	30,30 ±10,98	32,80 ±9,99	32,24 ±10,22	29,01 ±11,37	0,362 (0,147)	0,211 (0,237)	0,785 (0,058)
Maximum	Initiating	47,70 ±12,42	49,68 ±11,81	49,65 ±11,53	45,79 ±13,28	0,487 (0,106)	0,217 (0,233)	0,877 (0,053)
	Contralateral	46,26 ±11,57	48,57 ±10,62	48,18 ±10,70	44,80 ±12,17	0,324 (0,165)	0,259 (0,202)	0,741 (0,062)
Minimum	Initiating	21,79 ±11,01	22,59 ±9,70	22,72 ±10,24	20,71 ±11,13	0,737 (0,063)	0,466 (0,111)	0,923 (0,051)
	Contralateral	13,63 ±11,40	17,04 ±11,02	15,83 ±11,29	12,82 ±11,31	0,291 (0,182)	0,229 (0,223)	0,597 (0,082)
ROM	Initiating	25,91 ±3,34	27,09 ±8,43	26,93 ±6,33	25,08 ±3,91	0,392 (0,136)	0,200 (0,247)	0,879 (0,053)
	Contralateral	32,64 ±6,28	31,53 ±7,49	32,35 ±7,17	31,98 ±5,76	0,903 (0,052)	0,896 (0,052)	0,154 (0,296)
Knee Angle (degrees)								
At Foot Placement	Initiating	19,14 ±7,01	19,71 ±6,99	19,76 ±7,44	18,46 ±5,83	0,901 (0,052)	0,398 (0,133)	0,393 (0,135)
	Contralateral	19,73 ±6,48	20,40 ±7,00	20,37 ±7,11	19,11 ±5,54	0,970 (0,050)	0,337 (0,158)	0,167 (0,280)
At Foot Clearance	Initiating	15,30 ±7,24	14,41 ±6,87	14,81 ±6,90	15,33 ±7,58	0,483 (0,107)	0,836 (0,055)	0,466 (0,111)
	Contralateral	20,14 ±7,06	19,82 ±5,99	20,19 ±6,94	19,67 ±6,09	0,658 (0,072)	0,675 (0,070)	0,299 (0,178)
Maximum	Initiating	95,38 ±7,60	94,73 ±6,02	95,76 ±7,26	93,83 ±6,44	0,749 (0,062)	0,324 (0,165)	0,657 (0,072)
	Contralateral	94,31 ±7,20	94,83 ±7,07	95,32 ±7,20	92,73 ±6,72	0,528 (0,096)	0,218 (0,232)	0,554 (0,090)
Minimum	Initiating	12,08 ±6,40	11,61 ±5,10	12,23 ±5,82	11,21 ±6,20	0,663 (0,071)	0,490 (0,105)	0,424 (0,124)
	Contralateral	12,80 ±6,43	12,92 ±5,97	13,39 ±6,09	11,68 ±6,48	0,877 (0,053)	0,318 (0,168)	0,864 (0,053)
ROM	Initiating	83,30 ±5,71	83,12 ±4,73	83,53 ±5,42	82,61 ±5,21	0,950 (0,050)	0,595 (0,082)	0,762 (0,060)
	Contralateral	81,51 ±4,91	81,91 ±6,95	81,93 ±5,58	81,05 ±6,00	0,541 (0,093)	0,662 (0,072)	0,358 (0,149)
Ankle Angle (degrees)								
At Foot Placement	Initiating	-40,44 ±8,02	-39,42 ±6,58	-39,97 ±8,10	-40,27 ±6,12	0,625 (0,077)	0,829 (0,055)	0,983 (0,050)
	Contralateral	-38,50 ±6,54	-38,72 ±4,69	-38,44 ±5,86	-38,89 ±6,09	0,974 (0,050)	0,826 (0,055)	0,850 (0,054)
At Foot Clearance	Initiating	-46,55 ±5,62	-44,23 ±6,30	-45,88 ±6,13	-45,31 ±5,60	0,235 (0,218)	0,960 (0,050)	0,629 (0,076)
	Contralateral	-41,26 ±5,22	-42,35 ±4,17	-41,18 ±4,93	-42,71 ±4,64	0,463 (0,112)	0,299 (0,178)	0,750 (0,061)
Maximum	Initiating	11,51 ±5,11	11,76 ±8,45	11,40 ±6,47	12,03 ±6,62	0,788 (0,058)	0,679 (0,069)	0,557 (0,090)
	Contralateral	13,54 ±6,46	11,53 ±7,18	13,12 ±6,93	12,10 ±6,45	0,421 (0,125)	0,777 (0,059)	0,584 (0,084)
Minimum	Initiating	-48,41 ±5,52	-47,04 ±6,07	-47,81 ±6,01	-48,12 ±5,18	0,543 (0,092)	0,639 (0,075)	0,390 (0,136)
	Contralateral	-38,67 ±6,55	-36,78 ±11,13	-37,53 ±9,43	-38,93 ±6,04	0,483 (0,107)	0,426 (0,124)	0,572 (0,086)
ROM	Initiating	59,91 ±4,81	58,81 ±8,89	59,21 ±7,14	60,16 ±5,17	0,790 (0,058)	0,408 (0,130)	0,180 (0,267)
	Contralateral	52,20 ±6,33	48,31 ±14,08	50,66 ±11,18	51,03 ±6,89	0,249 (0,208)	0,622 (0,078)	0,389 (0,137)

Table 4 – Step cycle kinetic parameters group mean (± SD) differences in older adults with (HOF) and without history of fall (NHOF) and with (FOF) and without fear of falling (NFOF) when reaching level ground.

Stair Cycle Kinetics	Limb	NHOF (n=38)	HOF (n=22)	NFOF (n=41)	FOF (n=19)	Between Subjects Comparisons p value (observed power)		
						HOF	*FOF*	*HOF*FOF*
Hip Joint Power (W/Kg)								
At Heel-Strike	Initiating	-0,02 ±0,07	-0,00 ±0,12	-0,02 ±0,12	-0,00 ±0,12	0,222 (0,229)	0,263 (0,199)	0,056 (0,483)
Knee Joint Power (W/Kg)								
At Heel-Strike	Initiating	0,02 ±0,15	0,08 ±0,20	0,02 ±0,14	0,10 ±0,21	0,185 (0,261)	0,080 (0,417)	0,212 (0,237)
Ankle Joint Power (W/Kg)								
At Heel-Strike	Initiating	-0,05 ±0,10	-0,04 ±0,08	-0,02 ±0,08	-0,08 ±0,10	0,270 (0,195)	**0,026 (0.612)**	0,260 (0,201)

Gait cycle kinematic and kinetic parameters after stair descent

The kinematic and kinetic descriptive statistics of the gait cycle are summarized in Table 5 and 6, respectively.

Regarding lower limb kinematics, older adults with HoF exhibited significantly reduced initiating ankle angle at TO than older adults without HoF (p=0,015). The FOF group presented a significantly reduced initiating ankle angle at HS (p=0.041) and TO (p=0.026) when compared to the NFOF group. Older adults with FoF exhibited significantly reduced contralateral ankle angle at TO when compared to older adults without FoF (p=0.022). There was no interaction between HoF and FoF for any dependent variable.

Regarding lower limb kinetics, older adults with HoF presented a significantly increase in the initiating hip joint power at HS (p=0,024) and contralateral ankle joint power at TO (p=0,029) when compared to older adults without HoF. There was no interaction between HoF and FoF for any dependent variable.

There was a tendency towards existing statistically significantly differences between the NHOF and HOF groups in the contralateral hip joint power at HS, in the initiating ankle joint power at HS and TO, and in the contralateral ankle joint power at HS. All of the previous variables were increased in the HOF group when compared to the NHOF group. There was also a tendency towards existing statistically significant differences between older adults with and without FoF in the initiating knee joint power at HS. The aforementioned was increased in the FOF group when compared to the NFOF group.

Table 5 – Gait cycle kinematic parameters group mean (± SD) differences in older adults with (HOF) and without history of fall (NHOF) and with (FOF) and without fear of falling (NFOF) after reaching level ground and walking two steps forward.

Gait Cycle Kinematics	Limb	**NHOF (n=38)**	**HOF (n=22)**	**NFOF (n=41)**	**FOF (n=19)**	Between Subjects Comparisons p value (observed power) *HOF*	*FOF*	*HOF*FOF*
Hip Angle (degrees)								
At Heel-Strike	Initiating	27,68 ±10,43	26,36 ±10,40	26,84 ±10,57	27,97 ±10,09	0,522 (0,007)	0,705 (0,003)	0,652 (0,004)
	Contralateral	43,02 ±10,96	42,66 ±10,51	42,56 ±10,78	43,58 ±10,81	0,845 (0,001)	0,739 (0,002)	0,924 (0,000)
At Toe-Off	Initiating	8,55 ±10,22	9,18 ±11,62	9,11 ±9,90	8,06 ±12,41	0,732 (0,002)	0,738 (0,002)	0,782 (0,001)
	Contralateral	8,95 ±9,33	9,10 ±10,36	9,25 ±9,83	8,47 ±9,45	0,837 (0,001)	0,818 (0,001)	0,715 (0,002)
Knee Angle (degrees)								
At Heel-Strike	Initiating	16,45 ±4,62	15,67 ±5,97	15,81 ±5,21	16,92 ±4,98	0,563 (0,006)	0,379 (0,014)	0,815 (0,001)
	Contralateral	14,28 ±6,38	16,27 ±7,47	14,21 ±6,98	16,72 ±6,27	0,483 (0,009)	0,285 (0,020)	0,621 (0,004)
At Toe-Off	Initiating	47,24 ±6,08	46,81 ±10,47	46,76 ±7,71	47,78 ±8,43	0,991 (0,000)	0,529 (0,007)	0,380 (0,014)
	Contralateral	48,82 ±7,33	47,88 ±8,80	48,64 ±8,09	48,12 ±7,46	0,794 (0,001)	0,921 (0,000)	0,768 (0,003)
Ankle Angle (degrees)								
At Heel-Strike	Initiating	-39,98 ±6,66	-38,80 ±7,09	-40,87 ±6,37	-36,68 ±6,91	0,870 (0,000)	**0,041 (0,072)**	0,604 (0,005)
	Contralateral	-23,84 ±5,85	-25,32 ±5,97	-24,35 ±4,97	-24,46 ±7,66	0,224 (0,026)	0,910 (0,000)	0,260 (0,023)
At Toe-Off	Initiating	-30,61 ±6,17	-29,68 ±7,04	-31,66 ±6,59	-27,26 ±5,11	**0,015 (0,000)**	**0,026 (0,085)**	0,280 (0,021)
	Contralateral	-27,50 ±4,83	-26,89 ±5,96	-28,38 ±4,96	-24,90 ±5,13	0,980 (0,000)	**0,022 (0,091)**	0,868 (0,000)

Table 6 – Gait cycle kinetic parameters group mean (± SD) differences in older adults with (HOF) and without history of fall (NHOF) and with (FOF) and without fear of falling (NFOF) after reaching level ground and walking two steps forward.

Gait Cycle Kinetics	Limb	**NHOF (n=38)**	**HOF (n=22)**	**NFOF (n=41)**	**FOF (n=19)**	Between Subjects Comparisons p value (observed power)		
						HOF	***FOF***	***HOF*FOF***
Hip Joint Power (W/Kg)								
At Heel-Strike	Initiating	0,02 ±0,10	-0,06 ±0,15	0,00 ±0,12	-0,03 ±0,14	**0,024 (0,087)**	0,520 (0,007)	0,506 (0,008)
	Contralateral	-0,00 ±0,16	0,09 ±0,17	0,04 ±0,20	0,01 ±0,06	0,073 (0,056)	0,217 (0,027)	0,256 (0,023)
At Toe-Off	Initiating	-0,13 ±0,60	-0,32 ±0,50	-0,21 ±0,60	-0,17 ±0,50	0,136 (0,039)	0,791 (0,001)	0,314 (0,018)
	Contralateral	0,14 ±0,66	0,37 ±0,45	0,25 ±0,65	0,17 ±0,48	0,124 (0,042)	0,551 (0,006)	0,605 (0,005)
Knee Joint Power (W/Kg)								
At Heel-Strike	Initiating	-0,01 ±0,19	-0,05 ±0,24	0,01 ±0,18	-0,10 ±0,24	0,837 (0,001)	0,081 (0,053)	0,435 (0,011)
	Contralateral	-0,15 ±0,41	-0,20 ±0,46	-0,19 ±0,50	-0,13 ±0,18	0,644 (0,004)	0,563 (0,006)	0,933 (0,000)
At Toe-Off	Initiating	-0,36 ±0,35	-0,20 ±0,36	-0,36 ±0,37	-0,23 ±0,31	0,560 (0,006)	0,334 (0,017)	0,382 (0,014)
	Contralateral	-0,60 ±0,40	-0,53 ±0,37	-0,60 ±0,38	-0,53 ±0,41	0,309 (0,018)	0,503 (0,008)	0,198 (0,029)
Ankle Joint Power (W/Kg)								
At Heel-Strike	Initiating	0,65 ±1,64	1,22 ±1,39	1,05 ±1,45	0,45 ±1,76	0,051 (0,066)	0,169 (0,033)	0,146 (0,037)
	Contralateral	-0,04 ±0,10	-0,07 ±0,10	-0,05 ±0,11	-0,05 ±0,08	0,080 (0,054)	0,756 (0,002)	0,247 (0,024)
At Toe-Off	Initiating	-0,06 ±0,27	-0,18 ±0,24	-0,11 ±0,28	-0,11 ±0,24	0,085 (0,052)	0,797 (0,001)	0,875 (0,000)
	Contralateral	0,02 ±0,24	0,14 ±0,18	0,08 ±0,22	0,05 ±0,25	**0,029 (0,082)**	0,555 (0,006)	0,378 (0,014)

Discussion

This study aimed to evaluate the influence of HoF and FoF on spatio-temporal parameters including task velocity and time, single and double-support time, peak downwards CoM velocity and kinematic and kinetic parameters, such as, hip, knee and ankle angles, ROM and joint power, as well as, FC and FP on older adults during stair descent and gait transition.

At baseline participants exhibited similar characteristics regarding age, gender, BMI, health conditions and prescribed medication, as well as, cognitive and PA conditions, functional mobility and ADL's performance. The probability of falling increases with age (29) and previous literature has reported that one third of the community-dwelling population aged over 60 experiences at least one fall per year (27), the participants who exhibited HoF in our study corroborate these findings. Gender differences on stair negotiation have been previously reported showing that women present higher risk of falling and prevalence of falls on stairs (36), the female ratio in our study in the participants with HoF support these findings. Excessive body weight has been reported to contribute to a reduction in the ability to perform ADL's, such as stair negotiation, and therefore, it has been associated with falls in older adults (51). Accordingly, the current study shows that older adults with FoF are more likely to fall due to the significantly higher BMI when compared to older adults without FoF. Polypharmacy has been reported to be one of the major factors in risk of falling (29), so much so, that there's a specific category of medications denominated as "Fall-Risk Increasing Drugs" (FRID's). FRID's can influence risk of falling by adversely affect the cardiovascular or the central nervous system (50). The participants with HoF in our study corroborate these findings presenting a combination of prescribed medications that can be considered FRID's.

When it came to functional mobility performance, our results are in accordance with the inclusion criteria of our community-dwelling healthy older adults sample, with participants showing a consistent ability to move safely and independently. A TUG score of ≥13.5 seconds and a FTSTS score of >12 seconds have been used to identify older adults at a higher risk of falling (48, 83). We could not find significant differences regarding the TUG score, with the mean score of both older adults with HoF and FoF being lower than 13,5 seconds. However, the results of our study show that the participants with HoF and FoF were at a higher risk of falling scoring longer than 12 seconds in the FTSTS. Our results also demonstrate that older adults with HoF and FoF are at a higher risk of suffering a recurrent fall, as it has been stated by Teo et al., (2013), that a FTSTS score longer than 15 seconds could predict an increased risk of recurrent falls (74%) in healthy older adults (90). To the best of our knowledge a HGS cut-off that predicts the risk of falling hasn't been estimated, however, loss of muscle mass and strength has been established as an important risk factor for falls, therefore, lower HGS could very well be related as well (82). Comparing our results to the data provided by Mendes et al., (2017) who established that the average HGS for Portuguese older adults was 30,3Kg among men and 18Kg among women (84), it's possible to assume that our participants presented reasonable HGS.

Regarding spatio-temporal parameters, in line with previous reports, our results showed that older adults with HoF and FoF adopt conservative strategies, descending stairs slower and more cautiously to avoid falling (34). It has been stated that gait velocity is the most consistent change associated with age, diminishing 1% per year from the age of 60 onwards (16, 18) being responsible for a 7% increase of falls (18). Accordingly, Jacobs et al., (2016) also reported that older adults descend stairs slower (23), our results support these findings, with both HoF and FoF groups presenting reduced task velocity and time. This may indicate that older adults use a more conservative and cautious strategy to maintain dynamic balance to prevent falls (104). Previous literature has found that at level gait and during stair descent older adults show increased double-support time (18, 23), which may be the result of a weaker swing limb advancement because of muscle power loss, as well as, decreased trunk and lower limbs stability (18). This also indicates that older adults may require more time after the limb advancement to maintain weight-bearing stability (104). Accordingly, Kwon et al., (2018) found that at level gait older adults with HoF exhibit increased double-support time, however, in our study only the older adults with FoF presented longer double-support time when compared to older adults without FoF.

The results of the current study also demonstrate that participants with HoF and FoF present decreased peak downwards CoM velocity. This finding is in accordance with Bosse et al., (2012) who examined the dynamic stability control during stair descent and found that when compared to younger adults, older adults are at greater risk of falling due to less ability in safely control the body's CoM while stepping down (41). Our results are also in accordance with Buckley et al., (2013) who investigated CoM vertical velocity profiles, reporting that peak downwards CoM velocity was significantly reduced by age. Previous literature has also found that older adults may adopt a stair descent strategy where CoM downwards velocity is limited to decrease fall risk (43, 44) with the reduced peak occurring more or less at the instant of contact with the step below (42).

Greater FP (43) and reduced FC have been associated with a higher risk of falling during stair negotiation (37). Kunzler et al., (2018) reported that falls during stair descent are more likely to occur near the bottom of the staircase, when older adults tread on the last step, so it was important to analyze FC and FP during this transition. Our results showed that older adults with and without HoF and FoF present similar strategies when negotiating FP and FC, leaving and reaching the steps with reasonable distance in a safely manner. Francksen et al., (2020) analyzed the influence of age and step height inconsistency on FP and FC, reporting significantly greater FP in older adults, when comparing the same steps. The study states that this finding is related to more cautious stepping strategies adopted by older adults, which increase the chances of overstepping and the foot to slip forwards over the edge, causing a backward loss of balance and possibly a fall (43). Francksen et al., (2020), could not establish an association between age and changes in FP and FC on the last step, similar to our results, that were not able to associate HoF and FoF with lower FC and greater FP. This can be related to the chosen moment of FP and FC data extraction in both protocols given that when the limb leaves the last step and initiates gait transition, the vertical and horizontal distance of the foot to the step is considerably higher because there's no step below to limit its trajectory (42).

Within the stair cycle, it was important to analyze the lower limb joint angles at the moment of the aforementioned events, their minimum and maximum angles, and ROM because their reduction in older adults has been reported to result in a higher risk of falling (29). Our results do not demonstrate the influence of HoF and FoF on lower limb kinematics, given that the participants exhibit similar position angles. It's also not possible to compare our results to other studies, given that to the best of our knowledge, no author focused on the lower limb joint position at the specific events of FC and FP. Comparing the present results with those of Gerstle et al., (2021), who analyzed lower limb ROM on younger and older females with and without HoF, our participants presented higher ROM. However, this study also could not establish an influence of HoF on ROM, only finding significant correlations with age (49).

Previous literature has stated that impaired lower limb strength and power were significant predictors of limited physical performance and functional mobility in community-dwelling older adults (21) as well as risk of falling (29). It has also been established that due to the age-related decrease in maximal force, older adults usually operate closer to their maximal capacities during stair descent, and consequently, it becomes more challenging than most ADL's (110). In the stair cycle, regarding joint power we analyzed the bottom transition, when the initiating limb reaches level ground, reported to be the moment when it's most likely for a fall to occur (37). Our results showed that when descending the last step, older adults presented eccentric work at hip and ankle joints (expressed as a negative power) and concentric work at knee joint (expressed as a positive power). Previous literature has established that during stair descent older adults exhibit reduced ankle power associated with an utilization of smaller and weaker ankle plantarflexors (45, 54). However, our results do not correlate with these findings, with older adults with FoF exhibiting significantly increased ankle joint power at HS. This disparity can be explained by Browne et al., (2019) analysis of a novel ankle power biofeedback paradigm to encourage favorable biomechanical adaptations in older adults. The authors reported that older adults can volitionally modulate ankle power at their preferred walking velocity, showing that they retain the capacity for more youthful patterns of joint power generation, especially, those with reduced levels of incapacity such as our sample (113).

In the gait cycle, we analyzed lower limb joint angles at HS and TO after stair descent. These events are the most significant given that previous literature has found that older adults present altered lower limb joint motion (11) resulting in limited capacity in limb advancement during gait (18, 102). Our results showed that participants exhibited similar angles in the hip and knee joints, however, regarding the ankle older adults with HoF and FoF adopted different position angles. This resulted in different ankle strategies, specifically, diminished ankle dorsiflexion at HS and diminished plantarflexion at TO.

Reduced hip and ankle angles are the most consistent finding among older adults (103, 104), however, we can only report significant differences regarding the ankle in participants with

HoF and FoF. Our study found that older adults with FoF adopted significantly reduced initiating ankle angles at HS, in accordance with Arnold et al., (2014) that compared older and younger adults, reporting reduced ankle dorsiflexion at HS in older adults. We can also report that older adults with HoF and FoF adopted significantly reduced initiating ankle angles at TO with the latter also exhibiting reduced contralateral ankle angles at TO, in accordance with Arnold et al., (2014) that reported reduced plantarflexion at TO in older adults.

Regarding joint power in the gait cycle after stair descent, our results highlight the initiating ankle at HS as the strongest joint power achieved by the participants. This finding also does not align with the previous literature that has focused on older adults at level gait and established a less efficient ankle power as the most consistent finding (10, 18, 20). Similarly, to our results in the stair cycle, this inconsistency can be explained by Browne et al., (2019) who found that older adults can deliberately adapt ankle power at their self-selected walking velocity. We can report that older adults with HoF exhibit significantly increased initiating hip joint power at HS and contralateral ankle joint power at TO than older adults without HoF. Older adults with HoF presented increased eccentric work at the hip at HS (expressed as a negative power) and concentric work at the ankle at TO (expressed as a positive power). These findings are in accordance with Meurisse et al., (2018), who reported that the weak plantarflexors force production could be compensated by a more flexed hip position allowing for an increase of the force generation by the hip extensors in older adults. This suggests a 'pull-off' rather than 'push-off' strategy for propulsion, consistent with the less plantarflexed calcaneus position at TO (10) and a distal-to-proximal redistribution that has been previously found in older adults, consisting of more reliance on the hip power output (113).

Several authors have focused on studying older adults during stair descent, however, to the best of our knowledge there's no previous literature that has evaluated the association between HoF and FoF. There are also few authors who have analyzed both stair descent and gait transition. Most of the existent literature only analyzes the influence of age in a sample of older and younger adults assuring different characteristics at baseline. Some authors studied different moments and strategies in older adults during stair descent and their step negotiation with irregular staircase characteristics. So, this study holds its pertinence in evaluating not only the association between HoF and FoF in older adults during stair descent but also during the gait transition. It also differentiates itself from the previous literature by including not only a spatio-temporal analysis but also a kinetic and kinematic one.

One limitation of the current study was related to the simulation of external conditions in the lab with the assumption that it would be representative of the daily-life conditions. However, controlled lab conditions do not include environmental and individual factors or other factors such as dual-tasking while descending stairs (101), so it wasn't fully possible to ensure this representation. Also, to ensure the data collection resembled daily-life conditions, participants wore usual and fitting clothes and shoes.

Future research may incorporate participants with a history of recurrent falls to analyze if they are related to higher incapacity levels causing more changes in spatio-temporal, kinematic and kinetic parameters during stair descent and gait transition. Future research should also consider differentiating the degrees of fear in participants with FoF to analyze if higher levels of FoF lead to more changes in the aforementioned parameters during stair descent and gait transition. In the future, it is important to identify other changes in spatio-temporal, kinematic and kinetic parameters in older adults during stair descent and gait transition that are associated with a higher risk of fall, to implement prevention strategies and, ultimately, reduce fall occurrence.

Conclusion

The current study analyzed the association between HoF and FoF on spatio-temporal and lower limb kinetic and kinematic parameters in older adults during stair descent and gait transition. FoF is associated with reduced gait and peak downwards CoM velocity, and longer double-support time. In the stair cycle, FoF is associated with increased initiating ankle power at HS. In the gait cycle, HoF is associated with reduced initiating ankle angle at TO and increased initiating hip power at HS and contralateral ankle power at TO. Also in the gait cycle, FoF is associated with a reduced initiating ankle angle at HS and TO and contralateral ankle angle at TO. These changes are consistent with more conservative strategies adopted by older adults during stair descent and gait transition to maintain dynamic stability and, consequently, avoid falling. Given that older adults with HoF and FoF are at a higher risk of falling and already display biomechanical changes during stair descent and gait transition, it is imperative to use these findings to implement prevention strategies and, ultimately, reduce the incidence of falls in this population.

Conflict of Interest Statement

The authors declare that they have no financial or personal conflicts to disclose.

References

1. United Nations. United Nations Decade of Healthy Ageing. Resolut Adopt by Gen Assem 14 December 2020. 2020;75(131):948–72.

2. Ansai JH, Aurichio TR, Rebelatto JR. Relationship between dual task walking, cognition, and depression in oldest old people. Int Psychogeriatrics. 2016;28(1):31–8.

3. Commission E. Population structure and ageing. Eurostat [Internet]. 2021;(July):1–10. Available from: http://ec.europa.eu/eurostat/statistics-explained/index.php/Population_structure_and_ageing

4. Census. Issn 0872-6493.

5. INE. Resident Population Projections 2080. Press Release [Internet]. 2020;1–21. Available from: www.ine.pt

6. Lamb DG, Correa LN, Seider TR, Diana M, Salazar L, Schwartz ZJ, et al. The aging brain: Movement speed and spatial control. 2019;105–11.

7. Jennifer MJ, Dempsey JA, Hellsten Y, Monette R, Kalmar JM. On the Horizon of Aging and Physical Activity Research. 2019;(December):1–18.

8. Marques NR, Laroche DP, Hallal CZ, Crozara LF, Morcelli MH, Karuka AH, et al. Association between energy cost of walking, muscle activation, and biomechanical parameters in older female fallers and non-fallers. Clin Biomech [Internet]. 2013;28(3):330–6. Available from: http://dx.doi.org/10.1016/j.clinbiomech.2013.01.004

9. Partridge L, Deelen J, Slagboom PE. Facing up to the global challenges of ageing. Nature [Internet]. 2018;561(7721):45–56. Available from: http://dx.doi.org/10.1038/s41586-018-0457-8

10. Arnold JB, Mackintosh S, Jones S, Thewlis D. Differences in foot kinematics between young and older adults during walking. Gait Posture [Internet]. 2014;39(2):689–94. Available from: http://dx.doi.org/10.1016/j.gaitpost.2013.09.021

11. Fhon JRS, Rodrigues RAP, Neira WF, Huayta VMR, Robazzi ML do CC. Fall and its association with the frailty syndrome in the elderly: Systematic review with meta-analysis. Rev da Esc Enferm. 2016;50(6):1003–10.

12. Barreto TMC. Physiopathology of cerebral aging and anti-aging mechanisms. uBibliorum [Internet]. 2020;1–54. Available from: http://hdl.handle.net/10400.6/10793

13. Audiffren J, Bargiotas I, Vayatis N, Vidal PP, Ricard D. A non linear scoring approach for evaluating balance: Classification of elderly as fallers and non-fallers. PLoS One. 2016;11(12):1–12.

14. Panagiotou M, Michel S, Meijer JH, Deboer T. The aging brain: sleep, the circadian clock and exercise. Biochem Pharmacol [Internet]. 2021;191(March):114563. Available from: https://doi.org/10.1016/j.bcp.2021.114563

15. Bair WN, Prettyman MG, Beamer BA, Rogers MW. Kinematic and behavioral analyses of protective stepping strategies and risk for falls among community living older adults. Clin Biomech (Bristol, Avon). 2016 Jul;36:74-82. doi: 10.1016/j.clinbiomech.2016.04.015. Epub 2016 Apr 29. PMID: 27228075; PMCID: PMC5568553.

16. Bertolini GN, de Alencar Silva BS, dos Santos VR, de Anchieta Messias I, Ribeiro JPJ, Marini E, et al. Are bioelectrical parameters and functionality associated with postural control in the elderly? Clin Biomech. 2021;82(April 2019).

17. van Kooten D, Hettinga F, Duffy K, Jackson J, Taylor MJD. Are there associations with age and sex in walking stability in healthy older adults? Gait Posture. 2018;60(November 2017):65–70.

18. Morfis P, Gkaraveli M. Effects of aging on biomechanical gait parameters in the healthy elderly and the risk of falling. J Res Pract Musculoskelet Syst. 2021;05(2):59–64.

19. Pawlaczyk N, Szmytke M, Meina M, Lewandowska M, Stępniak J, Bałaj B, et al. Gait analysis under spatial navigation task in elderly people—A pilot study. Sensors (Switzerland). 2021;21(1):1–12.

20. Meurisse GM, Bastien GJ, Schepens B. Effect of age and speed on the step-to-step transition phase during walking. J Biomech [Internet]. 2019;83:253–9. Available from: https://doi.org/10.1016/j.jbiomech.2018.12.001

21. Hinman MR, O'Connell JK, Dorr M, Hardin R, Tumlinson AB, Varner B. Functional predictors of stair-climbing speed in older adults. J Geriatr Phys Ther. 2014;37(1):1–6.

22. Dewolf AH, Meurisse GM, Schepens B, Willems PA. Effect of walking speed on the intersegmental coordination of lower-limb segments in elderly adults. Gait Posture [Internet]. 2019;70:156–61. Available from: https://doi.org/10.1016/j.gaitpost.2019.03.001

23. Jacobs J V. A review of stairway falls and stair negotiation: Lessons learned and future needs to reduce injury. Gait Posture [Internet]. 2016;49:159–67. Available from: http://dx.doi.org/10.1016/j.gaitpost.2016.06.030

24. Bet P, Castro PC, Ponti MA. Foreseeing future falls with accelerometer features in active community-dwelling older persons with no recent history of falls. Exp Gerontol [Internet]. 2021;143(September 2020):111139. Available from: https://doi.org/10.1016/j.exger.2020.111139

25. Marques NR, Hallal CZ, Spinoso DH, Morcelli MH, Crozara LF, Gonçalves M. Applying different mathematical variability methods to identify older fallers and non-fallers using gait variability data. Aging Clin Exp Res. 2017;29(3):473–81.

26. Hiyamizu M, Morioka S, Shomoto K, Shimada T. Effects of dual task balance training on dual task performance in elderly people: A randomized controlled trial. Clin Rehabil. 2012;26(1):58–67.

27. Cebolla EC, Rodacki ALF, Bento PCB. Balance, gait, functionality and strength:

Comparison between elderly fallers and non-fallers. Brazilian J Phys Ther. 2015;19(2):146–51.

28. Hansson EE, Valkonen E, Möller UO, Lin YC, Magnusson M, Fransson PA. Gait flexibility among older persons significantly more impaired in fallers than non-fallers—a longitudinal study. Int J Environ Res Public Health. 2021;18(13).

29. Ambrose AF, Paul G, Hausdorff JM. Risk factors for falls among older adults: A review of the literature. Maturitas [Internet]. 2013;75(1):51–61. Available from: http://dx.doi.org/10.1016/j.maturitas.2013.02.009

30. Rossler A, Wheeler JM, Thiamwong L. A Multidimensional Approach for Nurse Practitioners to Screen Fall Risk and Fear of Falling in Community-Dwelling Older Adults. J Nurse Pract [Internet]. 2023;19(1):104436. Available from: https://doi.org/10.1016/j.nurpra.2022.08.019

31. Muir SW, Berg K, Chesworth BM, Klar N, Speechley M. Modifiable risk factors identify people who transition from non-fallers to fallers in community-dwelling older adults: A prospective study. Physiother Canada. 2010;62(4):358–67.

32. Asai T, Oshima K, Fukumoto Y, Yonezawa Y, Matsuo A, Misu S. The association between fear of falling and occurrence of falls: a one-year cohort study. BMC Geriatr [Internet]. 2022;22(1):1–7. Available from: https://doi.org/10.1186/s12877-022-03018-2

33. MacKay S, Ebert P, Harbidge C, Hogan DB. Fear of Falling in Older Adults: A Scoping Review of Recent Literature. Can Geriatr J. 2021;24(4):379–94.

34. Ackermans TMA, Francksen NC, Casana-Eslava R V., Lees C, Baltzopoulos V, Lisboa PJG, et al. A novel multivariate approach for biomechanical profiling of stair negotiation. Exp Gerontol [Internet]. 2019;124(December 2018):110646. Available from: https://doi.org/10.1016/j.exger.2019.110646

35. Alcock L, O'Brien TD, Vanicek N. Biomechanical demands of the 2-step transitional gait cycles linking level gait and stair descent gait in older women. J Biomech [Internet]. 2015;48(16):4191–7. Available from: http://dx.doi.org/10.1016/j.jbiomech.2015.09.020

36. Singhal K, Kim J, Casebolt J, Lee S, Han KH, Kwon YH. Kinetic comparison of older men and women during walk-to-stair descent transition. Gait Posture [Internet]. 2014;40(4):600–4. Available from: http://dx.doi.org/10.1016/j.gaitpost.2014.07.004

37. Kunzler MR, Da Rocha ES, Dos Santos CS, Ceccon FG, Priario LA, Carpes FP. Should we consider steps with variable height for a safer stair negotiation in older adults? Work. 2018;59(1):15–21.

38. Kováčiková Z, Sarvestan J, Zemková E. Age-related differences in stair descent balance control: Are women more prone to falls than men? PLoS One. 2021;16(1 January):1–11.

39. Pierchała K, Lachowska M, Wysocki J, Morawski K, Niemczyk K. Evaluation of the sensory organization test to differentiate non-fallers from single- and multi-fallers.

Adv Clin Exp Med. 2019;28(1):35–43.

40. Woei-Nan Baira, Michelle G. Prettymana, Brock A. Beamerb and MWR. Kinematic and behavioral analyses of protective stepping strategies and risk for falls among community living older adults. Clin Biomech (Bristol, Avon). 2017;176(3):139–48.

41. Bosse I, Oberländer KD, Savelberg HH, Meijer K, Brüggemann GP, Karamanidis K. Dynamic stability control in younger and older adults during stair descent. Hum Mov Sci [Internet]. 2012;31(6):1560–70. Available from: http://dx.doi.org/10.1016/j.humov.2012.05.003

42. Buckley JG, Cooper G, Maganaris CN, Reeves ND. Is stair descent in the elderly associated with periods of high centre of mass downward accelerations? Exp Gerontol [Internet]. 2013;48(2):283–9. Available from: http://dx.doi.org/10.1016/j.exger.2012.11.003

43. Francksen NC, Ackermans TMA, Holzer D, Ebner SA, Maganaris CN, Hollands MA, et al. Negotiating stairs with an inconsistent riser: Implications for stepping safety. Appl Ergon [Internet]. 2020;87(July 2019):103131. Available from: https://doi.org/10.1016/j.apergo.2020.103131

44. Moniz-Pereira V, Kepple TM, Cabral S, João F, Veloso AP. Joint moments' contributions to vertically accelerate the center of mass during stair ambulation in the elderly: An induced acceleration approach. J Biomech [Internet]. 2018;79:105–11. Available from: https://doi.org/10.1016/j.jbiomech.2018.07.040

45. Foster RJ, Maganaris CN, Reeves ND, Buckley JG. Centre of mass control is reduced in older people when descending stairs at an increased riser height. Gait Posture [Internet]. 2019;73:305–14. Available from: https://doi.org/10.1016/j.gaitpost.2019.08.004

46. Dixon PC, Stirling L, Xu X, Chang CC, Dennerlein JT, Schiffman JM. Aging may negatively impact movement smoothness during stair negotiation. Hum Mov Sci. 2018;60(May):78–86.

47. Laudanski A, Brouwer B, Li Q. Measurement of lower limb joint kinematics using inertial sensors during stair ascent and descent in healthy older adults and stroke survivors. J Healthc Eng. 2013;4(4):555–76.

48. Di Giulio I, Reeves ND, Roys M, Buckley JG, Jones DA, Gavin JP, et al. Stair Gait in Older Adults Worsens With Smaller Step Treads and When Transitioning Between Level and Stair Walking. Front Sport Act Living. 2020;2(June).

49. Gerstle EE, O'Connor K, Keenan KG, Slavens BA, Cobb SC. The influence of age and fall history on single transition step kinematics. Clin Biomech [Internet]. 2021;89(August 2020):105456. Available from: https://doi.org/10.1016/j.clinbiomech.2021.105456

50. Lee J, Negm A, Peters R, Wong EKC, Holbrook A. Deprescribing fall-risk increasing drugs (FRIDs) for the prevention of falls and fall-related complications: a systematic review and meta-analysis. BMJ Open. 2021;11(2):1–10.

51. Mitchell RJ, Lord SR, Harvey LA, Close JCT. Associations between obesity and

overweight and fall risk, health status and quality of life in older people. Aust N Z J Public Health. 2014;38(1):13–8.

52. Ackermans TMA, Francksen NC, Casana-Eslava R V., Lees C, Baltzopoulos V, Lisboa PJG, et al. Stair negotiation behaviour of older individuals: Do step dimensions matter? J Biomech [Internet]. 2020;101:109616. Available from: https://doi.org/10.1016/j.jbiomech.2020.109616

53. Boyer KA, Johnson RT, Banks JJ, Jewell C, Hafer JF. Systematic review and meta-analysis of gait mechanics in young and older adults. Exp Gerontol [Internet]. 2017;95:63–70. Available from: http://dx.doi.org/10.1016/j.exger.2017.05.005

54. King SL, Underdown T, Reeves ND, Baltzopoulos V, Maganaris CN. Alternate stair descent strategies for reducing joint moment demands in older individuals. J Biomech [Internet]. 2018;78:126–33. Available from: https://doi.org/10.1016/j.jbiomech.2018.07.029

55. Paquette MR, Zhang S, Milner CE, Fairbrother JT, Reinbolt JA. Effects of increased step width on frontal plane knee biomechanics in healthy older adults during stair descent. Knee [Internet]. 2014;21(4):821–6. Available from: http://dx.doi.org/10.1016/j.knee.2014.03.006

56. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. J Clin Epidemiol. 2008;61(4):344–9.

57. Shumway-Cook A, Baldwin M, Pollisar N, Gruber W. Predicting the probability for falls in community-dwelling older adults. Phys Ther. 1997;77(8).

58. Lusardi MM, Fritz S, Middleton A, Allison L, Wingood M, Phillips E, et al. Determining Risk of falls in community dwelling older adults: A systematic review and meta-analysis using posttest probability. Vol. 40, Journal of Geriatric Physical Therapy. 2017. 1–36 p.

59. Moniz-Pereira V, Carnide F, Machado M, André H, 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(4):324–32.

60. Burns ER, Lee R, Hodge SE, Pineau VJ, Welch B, Zhu M. Validation and comparison of fall screening tools for predicting future falls among older adults. Arch Gerontol Geriatr [Internet]. 2022;101(April):104713. Available from: https://doi.org/10.1016/j.archger.2022.104713

61. Lavedán A, Viladrosa M, Jürschik P, Botigué T, Nuín C, Masot O, et al. Fear of falling in community-dwelling older adults: A cause of falls, a consequence, or both? PLoS One. 2018;13(3):1–14.

62. Toyoda H, Hayashi C, Okano T. Associations between physical function, falls, and the fear of falling among older adults participating in a community-based physical exercise program: A longitudinal multilevel modeling study. Arch Gerontol Geriatr [Internet]. 2022;102(May):104752. Available from: https://doi.org/10.1016/j.archger.2022.104752

63. Mooyeon Oh-Park, MD, Xiaonan Xue RH and JV. Transient Versus Persistent Fear of Falling in Community-Dwelling Older Adults: Incidence and Risk Factors. J Am Geriatr Soc. 2011;59(7):1225–1231.

64. Tombaugh TN, McIntyre NJ. The Mini-Mental State Examination : A Comprehensive Review. Am Geriatr Soc. 1992;922–35.

65. Baek MJ, Kim K, Park YH, Kim SY. The validity and reliability of the mini-mental state examination-2 for detecting mild cognitive impairment and Alzheimer's disease in a Korean population. PLoS One. 2016;11(9):1–19.

66. Guerreiro, M., Silva, A. P., Botelho, M., Leitão, O., Castro-Caldas, A., & Garcia C. Adaptation to portuguese population of the translated Mini Mental State Examination. Port Neurol J. 1994;1(9).

67. Ferreira AR, Martins S, Ribeiro O, Fernandes L. Validity and Reliability of the European Portuguese Version of Neuropsychiatric Inventory in an Institutionalized Sample. J Clin Med Res. 2015;7(1):21–8.

68. Santana I, Duro D, Lemos R, Costa V, Pereira M, Simões MR, et al. Mini-mental state examination: Screening and Diagnosis of Cognitive Decline, Using New Normative Data. Acta Med Port. 2016;29(4):240–8.

69. Tomioka K, Iwamoto J, Saeki K, Okamoto N. Reliability and validity of the international physical activity questionnaire (IPAQ) in elderly adults: The Fujiwara-kyo study. J Epidemiol. 2011;21(6):459–65.

70. Sember V, Meh K, Sorić M, Jurak G, Starc G, Rocha P. Validity and reliability of international physical activity questionnaires for adults across eu countries: Systematic review and meta analysis. Int J Environ Res Public Health. 2020;17(19):1–23.

71. Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, et al. International physical activity questionnaire: 12-Country reliability and validity. Med Sci Sports Exerc. 2003;35(8):1381–95.

72. Domingos C, Pêgo JM, Santos NC. Effects of physical activity on brain function and structure in older adults: A systematic review. Behav Brain Res. 2021;402.

73. Teixeira PJ, Marques A, Lopes C, Sardinha LB, Mota JA. Prevalence and preferences of self-reported physical activity and nonsedentary behaviors in Portuguese adults. J Phys Act Heal. 2019;16(4):251–8.

74. Mahoney FI BD. Functional Evalutation: The Barthel Index. Md State Med J. 1965;14:56–65.

75. Araújo F, Oliveira A, Pinto C, Ribeiro J. Validation of the Barthel Index in a sample of non-institutionalized elderly. Port J Public Heal. 2007;25(2):59–66.

76. Bouwstra H, Smit EB, Wattel EM, van der Wouden JC, Hertogh CMPM, Terluin B, et al. Measurement Properties of the Barthel Index in Geriatric Rehabilitation. J Am Med Dir Assoc [Internet]. 2019;20(4):420-425.e1. Available from: https://doi.org/10.1016/j.jamda.2018.09.033

77. Lawton M, Brody E. Assessment of older people: selfmaintaining and instrumental activities of daily living. Gerontologist. 1969;9:179–86. Gerontologist. 1969;9:1979–86.

78. Araújo, F., Pais Ribeiro, J., Oliveira. A., Pinto, C., & Martins T. Validation of the Lawton and Brody Scale in a sample of non-institutionalized elderly. Conf Pap Heal Psychol Natl Congr. 2007;217–20.

79. Justo-Henriques SI, Otero P, Torres ÁJ, Vázquez FL. Effect of long-term individual cognitive stimulation intervention for people with mild neurocognitive disorder. Rev Neurol. 2021;73(4):121–9.

80. Portela L, Sousa IM, Silvestre IM. Early Biomarkers of Sarcopenia : Systematic Literature Review. 2022;34:88–99.

81. Graf C. The Lawton Instrumental Activities of Daily Living (IADL) Scale. Best Pract Nurs Care to Older Adults, Hartford Inst Geriatr Nursing, New York Univ Coll Nurs. (23).

82. Benton MJ, Spicher JM, Silva-Smith AL. Validity and reliability of handgrip dynamometry in older adults: A comparison of two widely used dynamometers. PLoS One [Internet]. 2022;17(6 June):1–15. Available from: http://dx.doi.org/10.1371/journal.pone.0270132

83. Fess. Grip strength. Am Soc Hand Ther. 1992;4145.

84. Mendes J, Amaral TF, Borges N, Santos A, Padrão P, Moreira P, et al. Handgrip strength values of Portuguese older adults: A population based study. BMC Geriatr. 2017;17(1):1–12.

85. Peolsson A, Hedlund R, Oberg B. Intra- and inter-tester reliability and reference values for hand strength. J Rehabil Med. 2001;33(1):36–41.

86. Roberts HC, Denison HJ, Martin HJ, Patel HP, Syddall H, Cooper C, et al. A review of the measurement of grip strength in clinical and epidemiological studies: Towards a standardised approach. Age Ageing. 2011;40(4):423–9.

87. Muñoz-Bermejo L, Adsuar JC, Mendoza-Muñoz M, Barrios-Fernández S, Garcia-Gordillo MA, Pérez-Gómez J, et al. Test-retest reliability of five times sit to stand test (Ftsst) in adults: A systematic review and meta-analysis. Biology (Basel). 2021;10(6):1–10.

88. Doheny EP, Walsh C, Foran T, Greene BR, Fan CW, Cunningham C, et al. Falls classification using tri-axial accelerometers during the five-times-sit-to-stand test. Gait Posture [Internet]. 2013;38(4):1021–5. Available from: http://dx.doi.org/10.1016/j.gaitpost.2013.05.013

89. Jones SE, Kon SSC, Canavan JL, Patel MS, Clark AL, Nolan CM, et al. The five-repetition sit-to-stand test as a functional outcome measure in COPD. Thorax. 2013;68(11):1015–20.

90. Teo TWL, Mong Y, Ng SSM. The repetitive Five-Times-Sit- To-Stand test: Its reliability in older adults. Int J Ther Rehabil. 2013;20(3):122–32.

91. Goldberg A, Chavis M, Watkins J, Wilson T. The five-times-sit-to-stand test: Validity, reliability and detectable change in older females. Aging - Clin Exp Res. 2012;24(4):339–44.

92. Christopher A, Kraft E, Olenick H, Kiesling R, Doty A. The reliability and validity of the Timed Up and Go as a clinical tool in individuals with and without disabilities across a lifespan: a systematic review: Psychometric properties of the Timed Up and Go. Disabil Rehabil [Internet]. 2021;43(13):1799–813. Available from: https://doi.org/10.1080/09638288.2019.1682066

93. Barry E, Galvin R, Keogh C, Horgan F, Fahey T. Is the Timed Up and Go test a useful predictor of risk of falls in community dwelling older adults: A systematic review and meta- analysis. BMC Geriatr [Internet]. 2014;14(1):1–14. Available from: BMC Geriatrics

94. Podsiadlo, D; Richardson S. The Timed Up and Go: A Test of Basic Functional Mobility for Frail Elderly Persons. J Am Geriatr Soc [Internet]. 1991;39(2):142–8. Available from: https://pubmed.ncbi.nlm.nih.gov/1991946/

95. Steffen TM, Hacker TA, Mollinger L. Age- and Gender-Related Test Performance in Community-Dwelling Elderly People: Six-Minute Walk Test, Berg Balance Scale, Timed Up & Go Test, and Gait Speeds. Phys Ther. 2002;82(2):128–37.

96. Cappozzo a, Catani F, Della Croce U, Leardini a. Position and orietnation in space of bones during movement. Clin Biomech [Internet]. 1995;10(4):171–8. Available from: pdf AHa

97. Leardini A, Benedetti MG, Berti L, Bettinelli D, Nativo R, Giannini S. Rear-foot, mid-foot and fore-foot motion during the stance phase of gait. Gait Posture. 2007;25(3):453–62.

98. Leardini A, Biagi F, Merlo A, Belvedere C, Benedetti MG. Multi-segment trunk kinematics during locomotion and elementary exercises. Clin Biomech [Internet]. 2011;26(6):562–71. Available from: http://dx.doi.org/10.1016/j.clinbiomech.2011.01.015

99. Petuskey K, Bagley A, Abdala E, James MA, Rab G. Upper extremity kinematics during functional activities: Three-dimensional studies in a normal pediatric population. Gait Posture. 2007;25(4):573–9.

100. Singhal K, Kim J, Casebolt J, Lee S, Han KH, Kwon YH. Gender difference in older adult's utilization of gravitational and ground reaction force in regulation of angular momentum during stair descent. Hum Mov Sci [Internet]. 2015;41:230–9. Available from: http://dx.doi.org/10.1016/j.humov.2015.03.004

101. Ackermans T, Francksen N, Lees C, Papatzika F, Arampatzis A, Baltzopoulos V, Lisboa P, Hollands M, O'Brien T MC. Prediction of balance perturbations and falls on stairs in older people using a biomechanical profiling approach: A 12-month longitudinal study. Biomedgerontology. 2020;c:1–10.

102. Kang H. Sample size determination and power analysis using the G*Power software. J Educ Eval Health Prof. 2021;18:1–12.

103. Maranesi E, Merlo A, Fioretti S, Zemp DD, Campanini I, Quadri P. A statistical approach to discriminate between non-fallers, rare fallers and frequent fallers in older adults based on posturographic data. Clin Biomech [Internet]. 2016;32:8–13. Available from: http://dx.doi.org/10.1016/j.clinbiomech.2015.12.009

104. Kwon MS, Kwon YR, Park YS, Kim JW. Comparison of gait patterns in elderly fallers and non-fallers. Technol Heal Care. 2018;26(S1):S427–36.

105. Mishra P, Pandey CM, Singh U, Gupta A, Sahu C, Keshri A. Descriptive statistics and normality tests for statistical data. Ann Card Anaesth. 2019;22(1):67–72.

106. Alkarkhi AFM, Alqaraghuli WAA. Multivariate Analysis of Variance. Appl Stat Environ Sci with R. 2020;87–112.

107. Curtis K, Youngquist ST. Part 21: Categoric analysis: Pearson chi-square test. Air Med J [Internet]. 2013;32(4):179–80. Available from: http://dx.doi.org/10.1016/j.amj.2013.04.007

108. Jung SH. Stratified Fisher's exact test and its sample size calculation. Biometrical J. 2014;56(1):129–40.

109. Andrade C. The P Value and Statistical Significance: Misunderstandings, Explanations, Challenges, and Alternatives. Indian J Psychol Med. 2019;41(5):210.

110. Gaillardin F, Baudry S. Influence of working memory and executive function on stair ascent and descent in young and older adults. Exp Gerontol [Internet]. 2018;106(2017):74–9. Available from: https://doi.org/10.1016/j.exger.2018.02.022

111. Swanson R, Robinson KM. Geriatric Rehabilitation: Gait in the Elderly, Fall Prevention and Parkinson Disease. Med Clin North Am [Internet]. 2020;104(2):327–43. Available from: https://doi.org/10.1016/j.mcna.2019.10.012

112. Liang Y, Xu T, Qi S, Cao X, Yeung EHK, Hu Y. Non-age-related gait kinematics and kinetics in the elderly. BMC Musculoskelet Disord [Internet]. 2022;23(1):1–8. Available from: https://doi.org/10.1186/s12891-022-05577-2

113. Browne MG, Franz JR. Ankle Power Biofeedback Reverses the Distal-to-Proximal Redistribution in Older Adults. 2021;44–9.

Appendix

Appendix 1 – Ethics Committee Approval.

P.PORTO

ESCOLA
SUPERIOR
DE SAÚDE
POLITÉCNICO
DO PORTO

PARECER DA COMISSÃO DE ÉTICA

Número de Registo da Comissão de Ética: CE0064C Data receção do Documento: 27/04/2022. Existência de entradas anteriores: Não

TÍTULO DO TRABALHO:

Study and analysis of biomechanical parameters of human movement based on disability indicators in older adultsbased on a multifactorial analysis: a cross-sectional study

INVESTIGADOR RESPONSÁVEL:

Juliana dos Santos Moreira

DATA PREVISTA PARA A REALIZAÇÃO DO TRABALHO: Inicio: 1/05/2022 Fim: 3/05/2024

RESUMO DO ESTUDO

OBJETIVOS:

Nada a referir.

AMOSTRA:

Amostra de Conveniência recrutados a partir do Center for Rehabilitation Research of the Obra Diocesana de Promoção Social (ODPS) e do SAFHE Project.

FORMULÁRIO DE DADOS A RECOLHER:

Nada a referir

MATERIAL:

Nada a referir.

MÉTODOS:

Nada a referir.

Os dados pessoais cumprirão o regulamento (UE) 2016/679 do Parlamento e do Conselho Europeu e da lei portuguesa58/2019.

O anonimato e a confidencialidade dos dados serão garantidos, uma vez que o principal investigador atribuirá um código alfanumérico aos dados dos participantes.

Além disso, os dados só serão disponibilizados em um computador protegido com uma senha conhecida apenas pelo principal investigador

RISCOS:

Não existem

CONSENTIMENTO INFORMADO:

Nada a referir.

AUTORIZAÇÃO PELOS RESPONSÁVEIS LOCAIS:

Apresenta autorização da ATC de Fisioterapia, Termo de responsabilidade de orientadores,

APRECIAÇÃO DA COMISSÃO DE ÉTICA:

Termo de Consentimento Informado. Apresenta Pedido Institucional

PARECER FINAL DA COMISSÃO DE ÉTICA

De acordo com os dados analisados, o parecer é favorável desde que cumpridas todas as diretrizes submetidas a esta Comissão, recomendando-se que a decisão seja suspensa caso haja algum incumprimento grave.

25/05/2022 ______________________________

SGS ESS.004.MO.318.02

1 | 1

Appendix 2– Informed Consent Form.

ESCOLA
SUPERIOR
DE SAÚDE
POLITÉCNICO
DO PORTO

P.PORTO

TERMO DE
CONSENTIMENTO INFORMADO

Compete ao Investigador Principal, prestar aos Participantes do estudo as informações necessárias ao consentimento livre e esclarecido.
O termo de consentimento informado deve ser específico do Estudo de Investigação (o modelo deve ser adaptado ao estudo em causa, acrescentando outros dados considerados pertinentes ou eliminando partes não aplicáveis).

DESIGNAÇÃO DO ESTUDO: Estudo e análise biomecânica dos parâmetros do movimento humano baseado em indicadores de incapacidade em adultos mais velhos baseado numa análise multifatorial: um estudo observacional transversal

Declaração de Consentimento Informado

Conforme o RGPD, a Lei n.º 67/98 de 26 de Outubro e a "Declaração de Helsínquia" da Associação Médica Mundial (Helsínquia 1964; Tóquio 1975; Veneza 1983; Hong Kong 1989; Somerset West 1996, Edimburgo 2000; Washington 2002, Tóquio 2004, Seul 2008, Fortaleza 2013) – quando se aplicar

Eu, abaixo-assinado ____ fui informado de que o Estudo de Investigação acima mencionado se destina a **identificar determinantes biomecânicos a partir de diferentes tarefas funcionais, como a marcha, o sentar e levantar ou subir e descer escadas, tendo em consideração indicadores de incapacidade em adultos mais velhos, através de uma análise comparativa entre grupos com diferentes indicadores**.

Sei que neste estudo está prevista **o preenchimento de questionários e também a realização de medição da tensão arterial, medição da composição corporal, avaliação da força manual, realização das tarefas funcionais: sentar e levantar, marcha, subir e descer escadas, levantar, caminhar três metros, voltar e sentar e manter a posição de pé**, tendo-me sido explicado em que consistem e quais os seus possíveis efeitos.

Foi-me garantido que todos os dados relativos à identificação dos Participantes neste estudo são confidenciais e que será mantido o anonimato.

Sei que posso recusar-me a participar ou interromper a qualquer momento a participação no estudo, sem nenhum tipo de penalização por este facto ou interromper a qualquer momento a participação no estudo, sem nenhum tipo de penalização por este facto.

Compreendi a informação que me foi dada, tive oportunidade de fazer perguntas e as minhas dúvidas foram esclarecidas.

Aceito participar de livre vontade no estudo acima mencionado.

Também autorizo a divulgação dos resultados obtidos no meio científico, garantindo o anonimato.

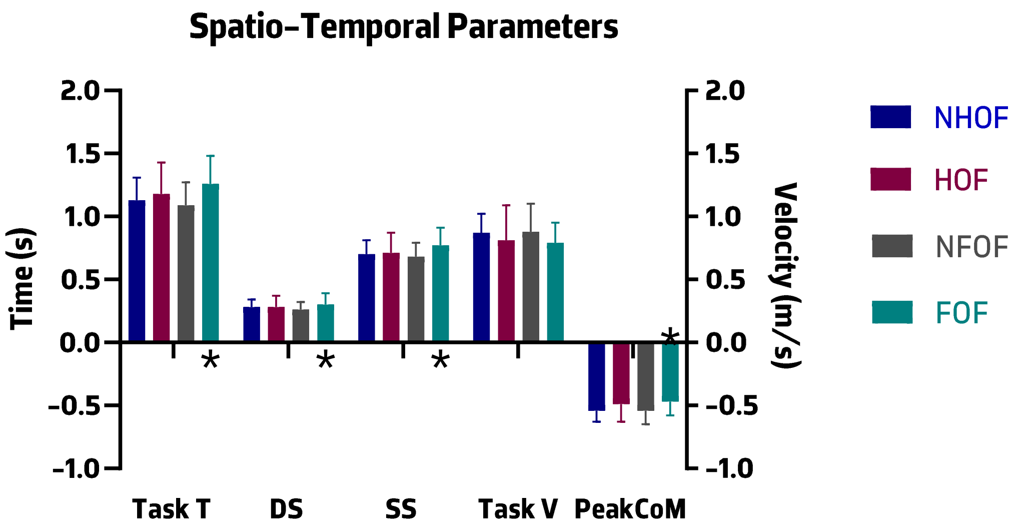
Nome do Investigador e Contacto: Juliana dos Santos Moreira, jmo@ess.ipp.pt.

___/___/______ ______________________________

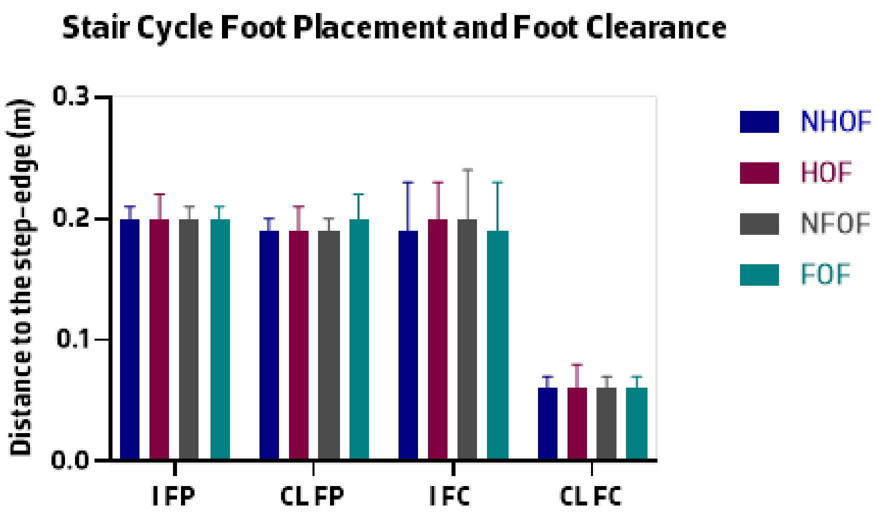
SGS ESS.0004.MO.317.02

1 | 1

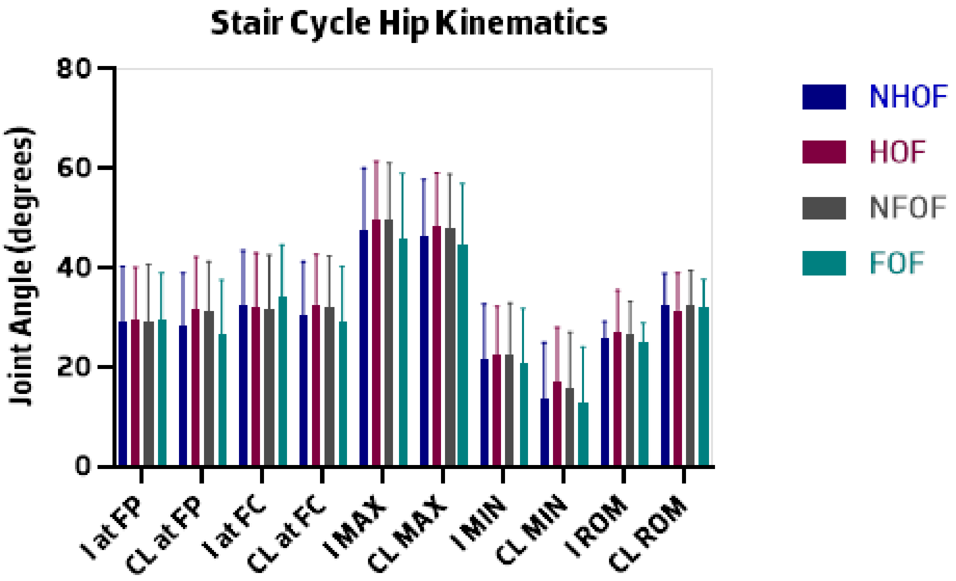
Appendix 3– Graphics of all the results.



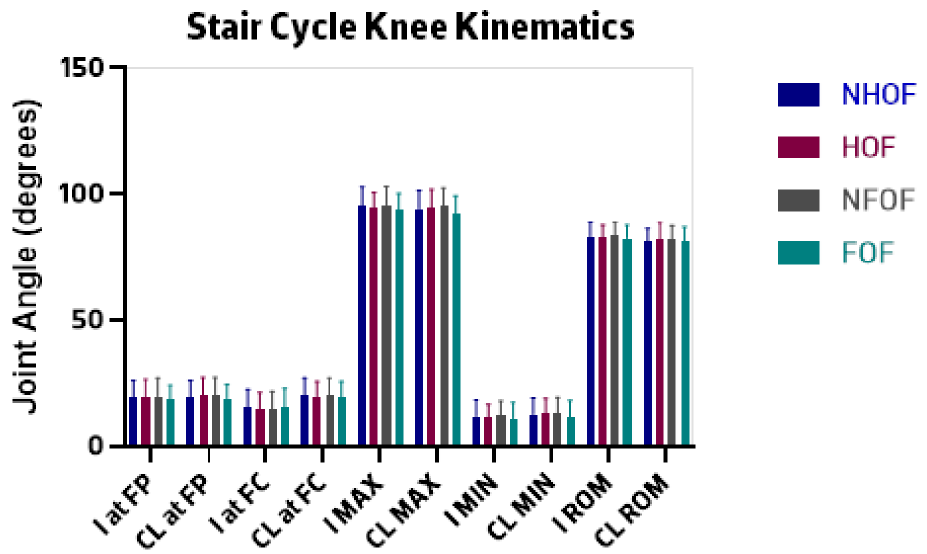
*Graphic 1 – Mean and standard deviation of task time (T) and velocity (V), double-support (DS) and single-support (SS) time and peak downwards CoM velocity (PeakCoM). *Statistically significant difference.*



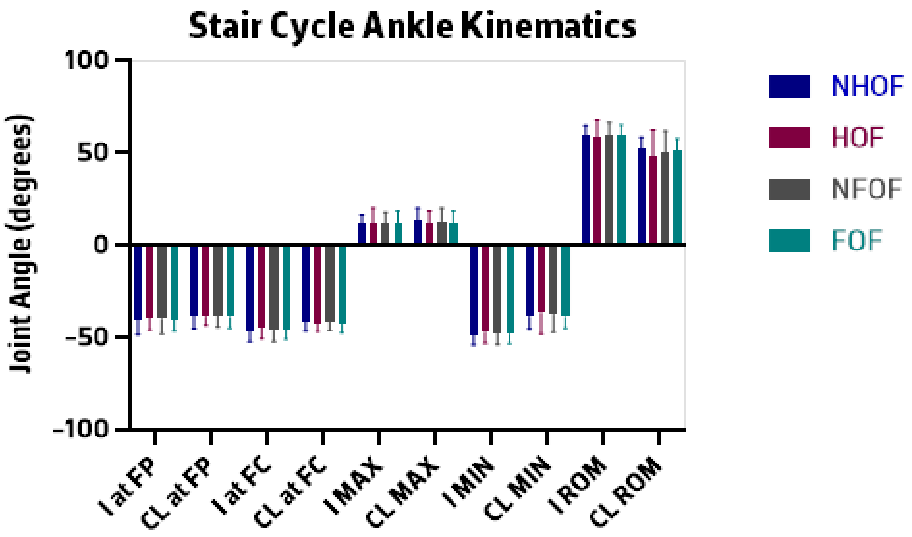
Graphic 2 – Mean and standard deviation of the foot placement (FP) and foot clearance (FC) in the initiating (I) and contralateral (CL) limb.



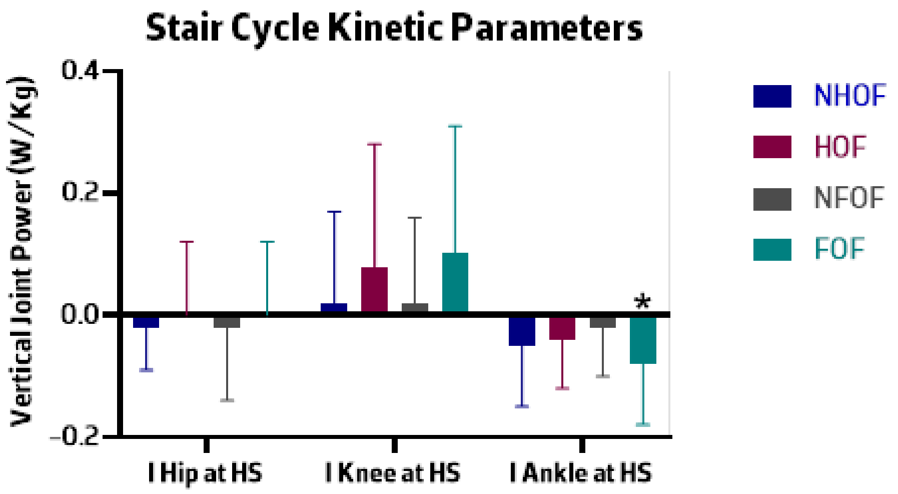
Graphic 3 – Mean and standard deviation of the hip angle at foot placement (FP) and at foot clearance (FC), maximum (MAX) and minimum (MIN) angle and range of motion (ROM) in the initiating (I) and contralateral (CL) limb.



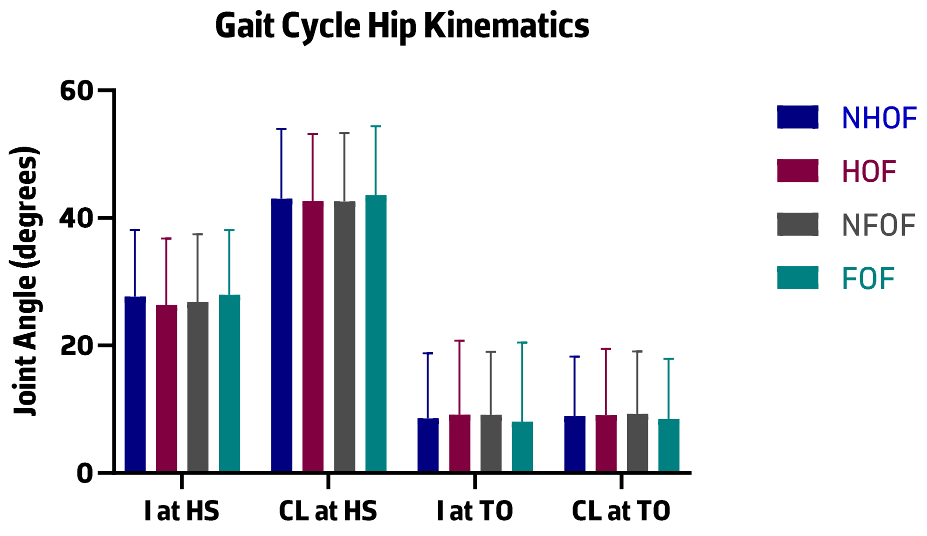
Graphic 4 – Mean and standard deviation of the knee angle at foot placement (FP) and at foot clearance (FC), maximum (MAX) and minimum (MIN) angle and range of motion (ROM) in the initiating (I) and contralateral (CL) limb.



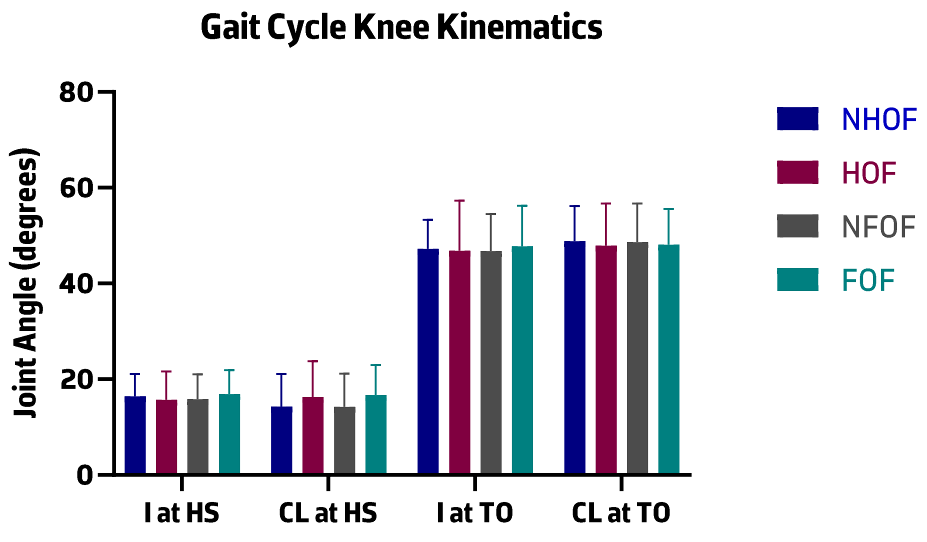
Graphic 5 – Mean and standard deviation of the ankle angle at foot placement (FP) and at foot clearance (FC), maximum (MAX) and minimum (MIN) angle and range of motion (ROM) in the initiating (I) and contralateral (CL) limb.



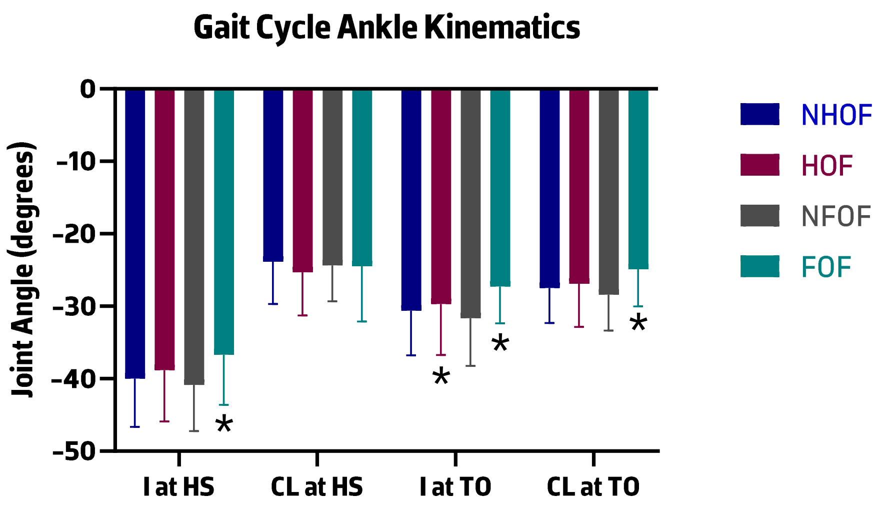
*Graphic 6 – Mean and standard deviation of vertical joint power of the hip, knee and ankle at heel-strike (HS) in the initiating limb (I). *Statistically significant difference.*



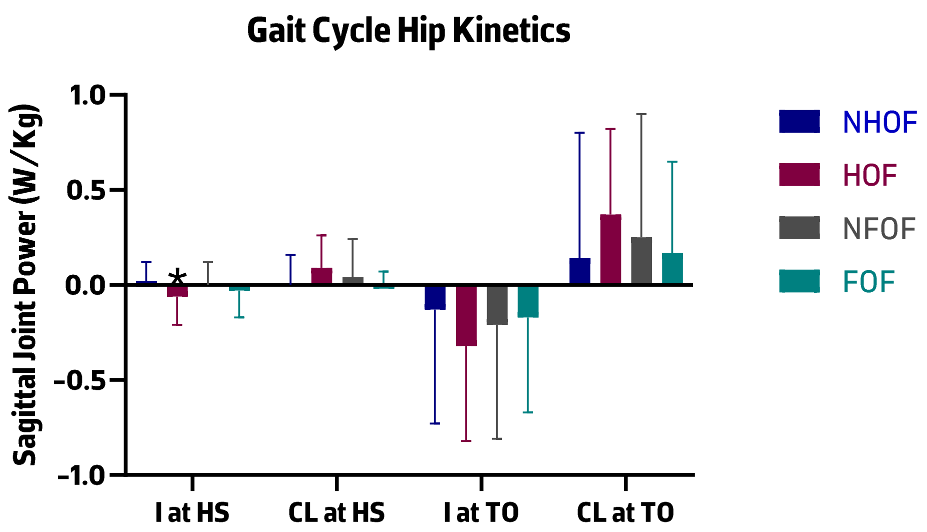
Graphic 7- Mean and standard deviation of the joint angle of the hip at heel-strike (HS) and toe-off (TO) in the initiating (I) and contralateral (CL) limb.



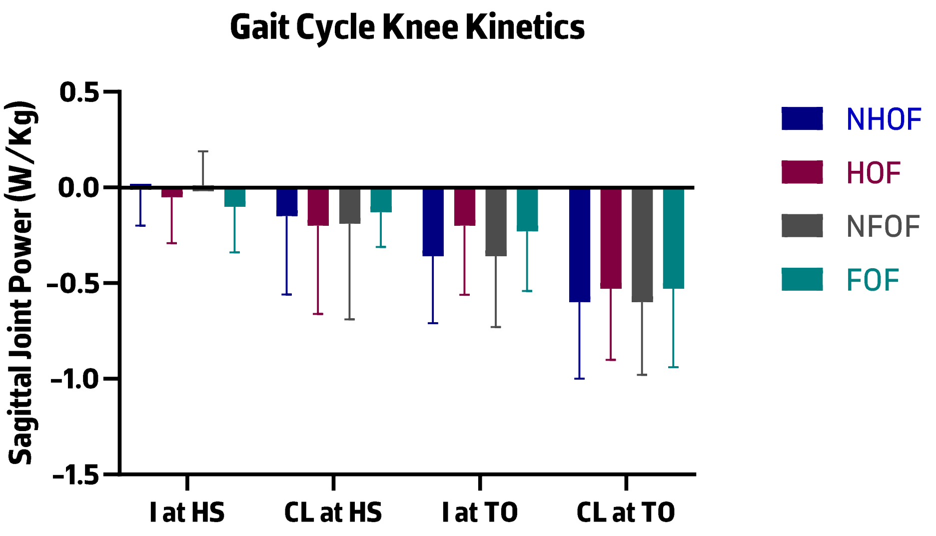
Graphic 8 - Mean and standard deviation of the joint angle of the knee at heel-strike (HS) and toe-off (TO) in the initiating (I) and contralateral (CL) limb.



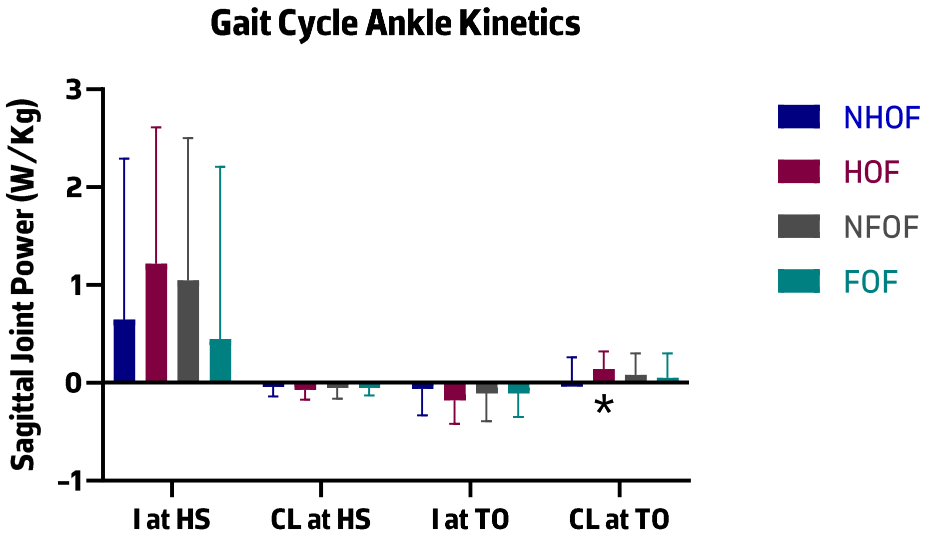
*Graphic 9- Mean and standard deviation of the joint angle of the ankle at heel-strike (HS) and toe-off (TO) in the initiating (I) and contralateral (CL) limb. *Statistically significant difference.*



*Graphic 10- Mean and standard deviation of sagittal joint power of the hip at heel-strike (HS) and toe-off (TO) in the initiating (I) and contralateral (CL) limb. *Statistically significant difference.*



Graphic 11 – Mean and standard deviation of sagittal joint power of the knee at heel-strike (HS) and toe-off (TO) in the initiating (I) and contralateral (CL) limb.



*Graphic 12 – Mean and standard deviation of sagittal joint power of the ankle at heel-strike (HS) and toe-off (TO) in the initiating (I) and contralateral (CL) limb. *Statistically significant difference.*