engineering proceedings

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Proceeding Paper

The Effect of an Interventional Movement Program on the Mechanical Gait Characteristics of a Patient with Dementia †

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† Presented at the Advances in Biomedical Sciences, Engineering and Technology (ABSET) Conference, Athens, Greece, 10–11 June 2023.

Abstract: We investigated the effect of an occupational therapy movement program (OTMP) on the specific mechanical characteristics of walking in a person with dementia. The hip joint of the patient's dominant limb was examined for flexion, extension, adduction, abduction, and internal or external rotation movements. This study included simple gait and dual-task gait conditions, with motor and cognitive tasks performed simultaneously. Neuropsychological scales and the gait analysis system (Vicon) were used to assess the patient pre- and post-intervention. Following the OTMP, statistically significant improvements were observed in hip movements, including flexion/extension, adduction/abduction, and internal/external rotation. These findings suggest that the OTMP can enhance hip mechanical gait characteristics and potentially contribute to functional independence in individuals with dementia.

Keywords: dementia; gait analysis; hip; occupational therapy

Citation: Vlotinou, P.; Tsiakiri, A.; Frantzidis, C.A.; Katsouri, I.-G.; Aggelousis, N. The Effect of an Interventional Movement Program on the Mechanical Gait Characteristics of a Patient with Dementia. *Eng. Proc.* **2023**, *50*, 4. https://doi.org/10.3390/engproc2023050004

Academic Editors: Dimitrios Glotsos, Spiros Kostopoulos, Emmanouil Athanasiadis, Efstratios David, Panagiotis Liaparinos and Ioannis Kakkos

Published: 27 October 2023

1. Introduction

Dementia is a complex neurodegenerative disorder characterized by progressive cognitive decline, including memory impairment, executive dysfunctions, and behavioral changes. Maintaining functional mobility, particularly gait, is a significant challenge for individuals with dementia. Gait disturbances, such as reduced walking speed, an altered stride length, and impaired balance, are prevalent and have a profound impact on their overall quality of life [1,2]. Interventional movement programs have emerged as a promising approach to improving gait characteristics in patients with dementia. These programs consist of structured physical exercises and activities aimed at enhancing motor control, muscle strength, and coordination. By targeting these aspects, interventional movement programs aim to address gait abnormalities and improve mobility and independence in individuals with dementia [3,4].

Although previous research has investigated the effects of interventional movement programs on gait performance in dementia, there is a paucity of studies focusing specifically on the impact of these interventions on hip biomechanics despite the crucial role of the hip joint in gait mechanics [5–9]. The hip joint plays a vital role in parameters such as stride length, walking speed, and balance, influencing the overall gait function [10]. Therefore, understanding the effects of interventional movement programs on hip biomechanics is essential for developing targeted interventions that can optimize gait performance and mitigate the risk of falls in individuals with dementia. To comprehensively evaluate the impact of interventional movement programs on hip biomechanics, advanced motion analysis techniques, such as three-dimensional gait analysis, can be employed. This technique enables the assessment of joint kinematics, kinetics, muscle activation patterns, and joint loading, providing valuable insights into the underlying mechanisms of gait improvement [11,12]. The present study aims to investigate the effect of an interventional movement program on mechanical gait characteristics, with a specific focus on hip biomechanics in patients with dementia. By examining changes in hip kinematics, kinetics, muscle activation patterns, and joint loading pre- and post-intervention, this study aimed to enhance our understanding of how interventional movement programs influence hip function during gait.

Using an Occupational Therapy Movement Program

Occupational therapy (OT) is essential to address dementia needs through personalized movement programs. It promotes independence and meaningful daily activities by tailoring interventions to individual preferences and abilities. OT evaluates cognitive, physical, and psychosocial aspects to identify movement challenges. With personalized goals, it targets impairments, limitations, and environmental barriers [8,9,13,14]. Tailored OT-based programs engage and motivate dementia individuals by integrating relevant activities and enhancing participation, identity, and well-being [10,11,15,16].

2. Methods Section

2.1. Participants

The present study involved a man 76 years old, who met the criterion for the diagnosis of vascular dementia and was diagnosed in the outpatient neurological clinic of dementia of the University Hospital of Alexandroupolis. The patient had no previous orthopedic surgery, no other neurological conditions that could affect their gait, no sensory deficits, and could understand and execute commands during gait analysis and during the occupational therapy motion program (OTMP). Our patient could walk independently for more than 100 m and had no psychiatric diagnosis. A cognitive assessment was performed (Mini-Mental State Examination, MMSE test: 21/30). Written consent was applied, and the patient was informed that they held the right to withdraw at any time he wished. The research was conducted under the acceptance of the Scientific Council of the University Hospital of Alexandroupolis.

2.2. Gait Analysis

A system of biomechanical analysis, Vicon(Vicon Motion Systems Ltd., Oxford, UK), was used for the evaluation of patient gait, consisting of 6 cameras (100 images/s) that were placed around a 12-m walking corridor with two power floors packed in the middle. Two piezoelectric dynamos (Kistler, 60 $\times$ 40 cm, Kistler Group, Winterthur, Switzerland) were used for the recording of ground-reaction forces (frequency 1000 Hz).

2.3. Gait Analysis Performance

The patient was informed about the gait analysis procedure. He was asked to keep his lower limbs uncovered, and self-adhesive reflectors were placed on the pelvis and lower extremities at specific anatomical points (posterior superior/anterior superior iliac spine, thigh, lateral femoral epicondyle, middle of the tibia, lateral malleolus, heels, 2nd metatarsal bone). The patient performed 10 gait attempts to become familiar with the procedure, and then he was asked to walk using his natural gait speed. Ten valid gait attempts were recorded and analyzed for every task (Figure 1).

The patient was examined both before and after the OTMP program and, in the same way, for (1) simple gait and (2) dual-motor task gait; this involved holding a tray with an empty glass in their dominant hand (elbow in flexion, 90° angle) and for (3), under dual-cognitive gait, walking while talking about specific object categories (fruits, clothes, furniture).

Figure 1. The patient had the process of gait analysis explained and was ready to begin the initial familiarization with natural gait speed.

2.4. OTMP

The occupational therapy movement program consists of a wide range of activities based on the activities of daily living and focusing on training specific mechanical characteristics of gait. The program was tailored according to the patient's needs in everyday living and was based on the occupational profile of the subject. In Table 1, the basic components of the program are presented.

Table 1. Examples of the structure of the OTMP that was implemented.

Task	Balance and Coordination	Range of Motion and Flexibility	Strengthening	Gait Training
Approach/Activities	e.g., Walking on different surfaces Standing on one leg and throwing or kicking a ball Putting cups on a cupboard while standing on a single leg	e.g., (using hip flexor stretches, calf, hamstring stretches). Bending or standing and collecting objects from different heights	e.g., Walking while holding 2 or more shopping bags With a bulky object in both hands Walking with pants filled with weights	e.g., Rhythmic stepping with music Coordinated arm swing while "skiing" Heel-to-toe walking from one room to another

2.5. Data Collection and Analysis

A 3D gait analysis system was used under Nexus software (version 2.12.1) and heel landing and take-off time for the dominant lower limb were recorded. The analysis of data was performed using Polygon software (version 4.4.6). The statistical analysis was performed using IBM SPSS Statistics version 24.0 [17].

In this study, the hip joint of a patient with dementia was selected as the focus of the investigation, specifically evaluating its movements in terms of flexion, extension, adduction, abduction, and internal or external rotation. This study was conducted under the following two different gait conditions: simple gait and dual-task gait. Dual-task gait involved performing a motor task, which entailed walking while holding a tray with an empty glass, or a cognitive task, which involved walking while engaging in verbal communication regarding specific object categories. Prior to and following the motor intervention program, the patient's cognitive function was assessed using neuropsychological scales, while a gait analysis system (Vicon) was employed to measure and analyze the hip joint movements during 30 gait attempts under all task conditions. The motor intervention program aimed to enhance the functional gait of the patient.

3. Results

The results of this study demonstrate significant improvements in hip joint movements following the implementation of the occupational therapy movement program (OTMP). The OTMP, which consisted of exercises based on activities of daily living, resulted in notable changes in the mechanical characteristics of walking.

3.1. Hip Flexion and Extension

From the results of the analysis of variance for repeated measures with the factors of "measurement" (pre, post) and the "measurement condition" (simple gait, dual+motor task, dual+cognitive task), a statistically significant interaction was observed ($F_{3,30} = 3.896$, $p < 0.05$, $\eta^2 = 0.280$). From the Bonferroni post hoc test, the flexion–extension angle of the right hip joint was found to be significantly greater ($p < 0.001$) following the implementation of the intervention program for all measurement conditions. Regarding the flexion and extension movements of the hip joint, during the simple gait condition, there was a significant increase in the range of motion from pre-intervention (17.22°) to post-intervention (21.93°). Similarly, in the dual-task condition with a motor component, the range of motion improved from 18.13° pre-intervention to 24.58° post-intervention. In the dual-task condition with a cognitive component, the range of motion increased from 17.27° pre-intervention to 22.66° post-intervention "Please see Figure 2a".

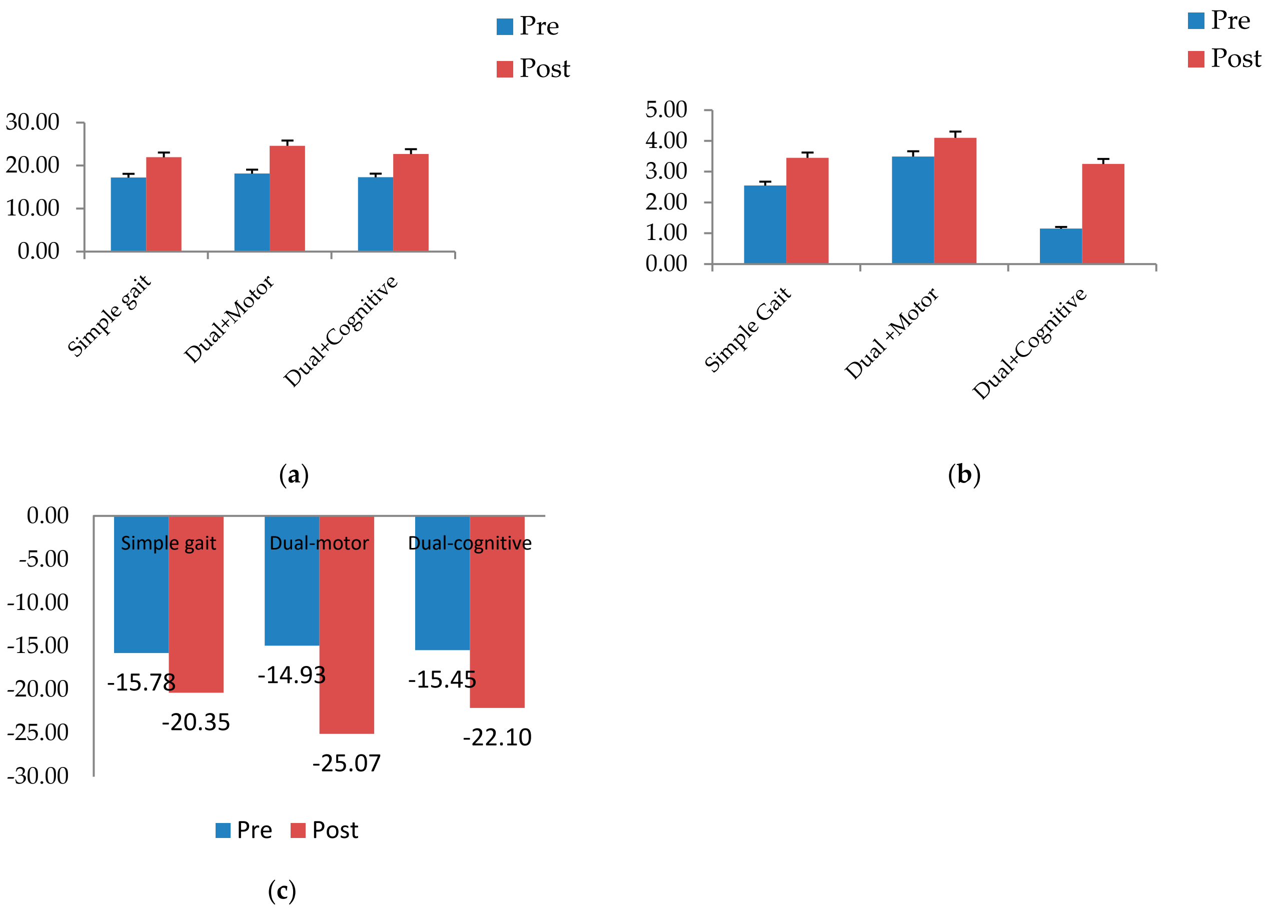

Figure 2. Effect of the OTMP on hip movements (**a**) Effect of the OTMP on the hip flexion–extension angle of the dominant lower limb, (**b**) Effect of the OTMP on the hip adduction–abduction angle for the dominant lower limb, (**c**) Effect of the OTMP on the hip internal–external rotation of the dominant lower limb.

3.2. Hip Adduction and Abduction

From the results of the analysis of variance for repeated measures with factors of "measurement" (pre, post) and "measurement condition" (simple gait, dual+motor task, dual+cognitive task), a statistically significant interaction was observed ($F_{3,30}$ = 2.845, $p < 0.05$, $\eta^2 = 0.574$). From the Bonferroni post hoc test, the adduction and abduction angle of the right hip joint was found to be significantly greater ($p < 0.01$) following the implementation of the intervention program for all measurement conditions. For adduction and abduction movements of the hip joint, there was a statistically significant increase in the range of motion. In the simple gait condition, the range of motion improved from 2.55° pre-intervention to 3.45° post-intervention. In the dual-task condition with a motor component, the range of motion increased from 3.49° pre-intervention to 4.10° post-intervention. In the dual-task condition with a cognitive component, the range of motion improved from 1.15° pre-intervention to 3.25° post-intervention "Please see Figure 2b".

3.3. Hip Internal and External Rotation

From the results of the analysis of variance for repeated measures with the factors of "measurement" (pre, post) and the "measurement condition" (simple gait, dual+motor task, dual+cognitive task), a statistically significant interaction was observed ($F_{3,30}$ = 29,650, $p < 0.001$, $\eta^2 = 0.723$). From the Bonferroni post hoc test, the internal and external rotation angle of the right hip joint was found to be significantly greater ($p < 0.01$). In internal and external rotation movements of the hip joint, significant improvements were observed. For the simple gait condition, the range of motion increased from −15.78° pre-intervention to −20.35° post-intervention. In the dual-task condition with a motor component, the range of motion improved from −14.93° pre-intervention to −25.07° post-intervention. In the dual-task condition with a cognitive component, the range of motion increased from −15.45° pre-intervention to −22.10° post-intervention "Please see Figure 2c".

Overall, the results indicate a statistically significant increase in the range of motion of hip movements following the OTMP ($p < 0.05$). These findings suggest that the OTMP effectively improved the mechanical characteristics of walking, specifically in terms of hip-joint movements.

4. Discussion

From the results of our research, the basic hypothesis that hip motion parameters can change under a structured program of motion activities based on everyday living (OTMP) is confirmed. Maintaining optimal hip movements is important as it could preserve gait performance in individuals with dementia. In a systematic review by Smith et al. [18], the authors evaluated the impact of occupational therapy on gait training in individuals with impairments in mobility. This review highlighted the positive effects of occupational therapy interventions, including improvements in gait parameters and functional mobility. Littbrand et al. [4] conducted a study focusing on older adults with limitations in mobility. They implemented a structured occupational therapy program and found significant improvements in gait performance and balance. They found that improvements in the hip range of motion, including flexion and abduction, were associated with enhanced balance and reduced dependence on activities of daily living. Smith et al. investigated the effects of a structured exercise program on hip movements in older adults with mobility limitations but with no cognitive deficits. Their results demonstrated an increase in hip flexion and an extension range of motion following the intervention. Furthermore, Buracchio et al. [3] investigated the effects of occupational therapy intervention on gait outcomes in individuals with neurodegenerative disorders. Their findings reveal improvements in gait speed and stride length following the intervention. In the same line, but with a different experimental group, Jones et al. [19] focused on the impact of a targeted rehabilitation program on hip movements in patients recovering from hip arthroscopy. They found significant improvements in hip abduction and the internal rotation range of motion after the intervention. While their study focused on a different population and intervention, observed improvements in hip movements align with our findings. This similarity could indicate that interventions targeting specific movements of the hip can effectively enhance the range of motion in these movements. Additionally, Brown et al. [20] investigated the effects of a specific exercise program on the hip joint range of motion in individuals with hip osteoarthritis. They reported significant increases in hip flexion, extension, abduction, and adduction range of motion after the intervention. Although their study population and intervention differed from ours, the observed improvements in hip movements align with our findings. This suggests that interventions targeting hip movements can lead to positive changes in the range of motion, regardless of the specific clinical population. Targeted interventions, including customized occupational therapy movement programs, structured exercise programs, and targeted rehabilitation, might have the potential to improve hip biomechanics and enhance functional mobility. These tailored interventions could result in positive changes in hip movement as they focus on specific impairments. Sled et al. [21] conducted a study examining the effects of a targeted exercise program on the hip range of motion in individuals with hip osteoarthritis. The results showed significant improvements in hip flexion, extension, abduction, and adduction, and a range of motion following the intervention. Comparing these findings with what we found, there were similarities in the improvements observed for the hip range of motion, indicating that targeted exercise interventions can effectively enhance hip mobility in individuals. Therefore, it can be concluded that interventions focused on improving hip movements have consistent effects across different populations and conditions, indicating the importance of addressing hip biomechanics in interventions aimed at enhancing functional mobility.

Limitations

Despite the interesting findings and contributions of this study, there are several limitations that should be acknowledged. Firstly, it should be emphasized that case studies inherently pose significant challenges in terms of generalizability. Secondly, this study focused on the specific mechanical characteristics of walking, particularly hip movements, without considering other aspects such as ankle movements, balance, stride length, or walking speed. While an improvement in hip biomechanics is a positive outcome, it is essential to examine the comprehensive impact of the occupational therapy movement program on overall gait performance and functional independence. Moreover, the study design was limited to pre- and post-intervention assessments without a control group. The lack of a control group restricts the ability to establish a causal relationship between the occupational therapy movement program and the observed improvements in hip movements. Future studies employing randomized controlled trials or comparative designs could provide more robust evidence. Despite these limitations, this study provides valuable insights into the potential benefits of an OTMP in improving specific mechanical characteristics of gait in individuals with dementia. These findings warrant further investigation and replication in larger and more diverse samples to establish the generalizability and effectiveness of such interventions.

5. Conclusions

The present study provides valuable insights into the effectiveness of an OTMP guided by gait analysis for improving the mechanical characteristics of walking in individuals with dementia. The improvement in the subject's hip motions could have important implications for gait performance and functional independence. The individualized and tailored nature of the occupational therapy approach allows for personalized interventions that address specific movement impairments and functional limitations. Nonetheless, this study underscores the important role of occupational therapy in optimizing gait mechanics and improving the overall well-being of individuals with dementia.

Author Contributions: Conceptualization, P.V. and N.A.; methodology, P.V. and C.A.F.; software, N.A.; validation, P.V. and N.A.; formal analysis, C.A.F. and N.A.; investigation, P.V and I.-G.K.; resources, P.V.; data curation, C.A.F. and I.-G.K.; writing—original draft preparation, P.V. and

A.T.; writing—review and editing, P.V., I.-G.K. and A.T.; visualization, C.A.F. and P.V.; supervision, N.A.; project administration, P.V. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of University General Hospital Of Alexandroupolis (1.68/06-04-2020) for studies involving humans.

Informed Consent Statement: Written informed consent was obtained from the patient(s) to publish this paper.

Data Availability Statement: Data may be made available upon personal request.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Montero-Odasso, M.; Verghese, J.; Beauchet, O.; Hausdorff, J.M. Gait and cognition: A complementary approach to understanding brain function and the risk of falling. *J. Am. Geriatr. Soc.* **2017**, *65*, 2611–2618. [CrossRef] [PubMed]
2. Ries, J.D.; Hutson, J.; Maralit, L.A.; Sankaranarayanan, S. Gait characteristics of individuals with dementia. *J. Geriatr. Phys. Ther.* **2009**, *32*, 53–57. [CrossRef]
3. Buracchio, T.; Dodge, H.H.; Howieson, D.; Wasserman, D.; Kaye, J.; Zitzelberger, T. The trajectory of gait speed preceding mild cognitive impairment. *Arch. Neurol.* **2019**, *66*, 312–317. [CrossRef] [PubMed]
4. Littbrand, H.; Rosendahl, E.; Lindelöf, N.; Lundin-Olsson, L.; Gustafson, Y.; Nyberg, L. A high-intensity functional weight-bearing exercise program for older people dependent in activities of daily living and living in residential care facilities: Evaluation of the applicability with focus on cognitive function. *Phys. Ther.* **2009**, *89*, 573–585. [CrossRef]
5. Bruijn, S.M.; Meijer, O.G.; Beek, P.J.; van Dieën, J.H. Assessing the stability of human locomotion: A review of current measures. *J. R. Soc. Interface* **2013**, *10*, 20120999. [CrossRef] [PubMed]
6. Sanders, L.M.J.; Hortobágyi, T.; Karssemeijer, E.G.A.; Van der Zee, E.A.; Scherder, E.J.A.; van Heuvelen, M.J.G. Effects of low- and high-intensity physical exercise on physical and cognitive function in older persons with dementia: A randomized controlled trial. *Alzheimer's Res. Ther.* **2020**, *12*, 28. [CrossRef] [PubMed]
7. Kuan, Y.C.; Huang, L.K.; Wang, Y.H.; Hu, C.J.; Tseng, I.J.; Chen, H.C.; Lin, L.F. Balance and gait performance in older adults with early-stage cognitive impairment. *Eur. J. Phys. Rehabil. Med.* **2021**, *57*, 560–567. [CrossRef] [PubMed]
8. Casas-Herrero, A.; Anton-Rodrigo, I.; Zambom-Ferraresi, F.; Sáez de Asteasu, M.L.; Martinez-Velilla, N.; Elexpuru-Estomba, J.; Marin-Epelde, I.; Ramon-Espinoza, F.; Petidier-Torregrosa, R.; Sanchez-Sanchez, J.L.; et al. Effect of a multicomponent exercise programme (VIVIFRAIL) on functional capacity in frail community elders with cognitive decline: Study protocol for a randomized multicentre control trial. *Trials* **2019**, *20*, 362. [CrossRef] [PubMed]
9. Ghadiri, F.; Bahmani, M.; Paulson, S.; Sadeghi, H. Effects of fundamental movement skills based dual-task and dance training on single- and dual-task walking performance in older women with dementia. *Geriatr. Nurs.* **2022**, *45*, 85–92. [CrossRef] [PubMed]
10. Gebhard, D.; Mess, F. Feasibility and effectiveness of a biography-based physical activity intervention in institutionalized people with dementia: Quantitative and qualitative results from a randomized controlled trial. *J. Aging Phys. Act.* **2022**, *30*, 237–251. [CrossRef] [PubMed]
11. Howcroft, J.; Kofman, J.; Lemaire, E.D. Review of fall risk assessment in geriatric populations using inertial sensors. *J. Neuroeng. Rehabil.* **2016**, *13*, 1–17. [CrossRef] [PubMed]
12. Mentiplay, B.F.; Clark, R.A.; Mullins, A.; Bryant, A.L. Best practice models for Australian physiotherapists working with individuals in the severe and profound developmental disability sector. *BMC Health Serv. Res.* **2018**, *18*, 15.
13. Gitlin, L.N.; Arthur, P.B.; Piersol, C.V. Translation of a dementia caregiver intervention for delivery in homecare as a reimbursable Medicare service: Outcomes and lessons learned. *Gerontologist* **2018**, *58*, 47–59. [CrossRef] [PubMed]
14. Graff, M.J.; Vernooij-Dassen, M.J.; Thijssen, M.; Dekker, J.; Hoefnagels, W.H.; Rikkert, M.G. Community based occupational therapy for patients with dementia and their care givers: Randomised controlled trial. *BMJ* **2013**, *337*, a1659. [CrossRef] [PubMed]
15. Chung, J.C.; Lai, C.K.; Chung, P.M. Can the elderly learn to use a mobile device? A pilot study. *Clin. Interv. Aging* **2017**, *12*, 1571–1578.
16. Kolanowski, A.; Van Haitsma, K.S.; Penrod, J. Factors that relate to activity engagement in nursing home residents. *Am. J. Alzheimer's Dis. Other Dement.* **2015**, *30*, 558–567. [CrossRef] [PubMed]
17. IBM Corp. *IBM SPSS Statistics for Windows (Version 24.0)*; IBM Corp: Armonk, NY, USA, 2023.
18. Smith, S.C.; Laver, K.E.; Crotty, M.; Clemson, L.M. Occupational therapy interventions to improve gait and balance in adults with neurological conditions: A systematic review and meta-analysis. *Clin. Rehabil.* **2020**, *34*, 969–982.
19. Jones, C.A.; Gingrich, K.; Chapman, G. Clinical improvements in hip range of motion following a targeted rehabilitation program. *Int. J. Ther. Rehabil.* **2018**, *25*, 82–90. [CrossRef]

20. Brown, D.K.; Gage, W.H.; Polych, M.A.; Sleik, R.J.; Winder, T.R.; Gates, D.H. Does hip osteoarthritis severity associate with patient-reported outcomes, physical performance measures, or changes in these measures after hip exercise? *J. Orthop. Sports Phys. Ther.* **2016**, *46*, 388–396. [CrossRef]
21. Sled, E.A.; Sheehy, L.M.; Felson, D.T. Clinically important improvement in range of motion is seen by patients after total knee arthroplasty, including those with manipulation. *J. Rheumatol.* **2018**, *45*, 83–89.