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# Impact of Nordic walking on balance in women

A literature review

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## Abstract

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Nordic walking has been shown to be an effective method for improving balance, mobility, and overall health in women. Nordic walking has been shown to improve gait stability, prevent falling risk, and increase strength in the upper and lower limbs, maintaining functional independence. Apart from its physical advantages, the rhythm and social engagement in Nordic walking improve well-being, minimising anxiety and depression.

The aim of the literature review was to study the impact of Nordic walking on balance in women. This review demonstrates a systematic search done on databases from PubMed, CINAHL Complete (Ebsco), ProQuest Central, Wiley Online Library, and Sage Journals. Searches were conducted between October and December 2024 that focused on studies between 2019–2024, The initial search yielded 432 articles out of which 30 duplicates were removed. Following headline screening and evaluation of full-text availability, 53 articles were left. Further evaluation based on abstract relevance narrowed the selection to nine studies.

It was observed that Nordic walking enhances muscle strength, postural stability, and cognitive function, that benefits postmenopausal women in enhancing bone density, reducing the risk of osteoporosis, and improving overall physical health and with individuals with Parkinson's disease reducing symptoms such as tremors and rigidity. The incorporation of resistance shock absorber poles appears to improve bone health, particularly in the femur. Beyond its physiological effects, Nordic walking promotes social interaction, mitigates isolation, is helpful in weight control, and regulates blood pressure. Nordic walking is both low-cost and effective as an intervention and thus provides a means for improving balance and overall health among women with age-related mobility impairments.

Keywords: Nordic walking, balance, mobility, women's health, fall prevention, cognitive function, aging.

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## **Contents**

Abstract	2
1 Introduction	4
2 Theoretical background	5
2.1 Balance and mobility in women	8
2.2 Contributing factors to balance deficits and fall incidence in women	9
2.3 Prevalence of balance problems and falls	9
2.4 Current Interventions to improve balance	10
2.5 Characteristics of Nordic walking	10
2.6 Nordic walking and balance	11
3 Aim and data collection	11
4 Results	13
5 Discussion	24
References	27

## 1 Introduction

Nordic walking is a physical exercise that is recognised for the benefits to older adults. Nordic walking engages muscles of both the upper and lower body in an exercise that enhances strength, coordination, and stability, while the forces during movement are redistributed to reduce joint stress and promote more stable movement patterns. Nordic walking is an exercise for individuals with musculoskeletal conditions such as arthritis and osteoporosis, as it provides safer mobility than traditional walking and high intensity exercises with less stress on the joints. (Encarnación-Martínez et al.2023 35-40; Morano et al. 2024; Piotrowska et al. 2020; Nemoto et al. 2021: 209-215.) Nordic walking has found to improve cardiovascular health, increase muscle endurance and enhance postural stability. The benefits of Nordic walking contribute to a better gait pattern, reducing the risk of falls, since the activity also engages the core and upper body muscles that are usually not utilized in regular walking. Nordic walking demonstrates positive effects on mental health, including reductions in anxiety and depression and improvements in cognitive functioning addressing both the physical and cognitive challenges that are associated with aging. (Piotrowska, Guskowska,Leś,Rutkowska 2020; Wiacek,Natora, Zubrzycki and Tomasiuk 2023:865-870.)

Findings reported by Baggish (2022) and Nemoto et al. (2021), demonstrate the effectiveness of Nordic walking in improving cardiovascular health and muscular strength. Nordic walking engages more muscles and burns more calories than regular walking, with physical function, maximal walking speed, and cognitive function all improving over the walking group. Nordic walking activates up to 80 to 90% of the muscles, compared with 50% during normal walking, and uses 18% to 67% more energy than regular walking that helps to reduce fat mass, low density cholesterol and triglycerides, while enhancing muscle strength, endurance, and cardiovascular health. Engaging in exercising for more than once in a week demonstrated enhancement in cognition, handgrip strength, walking speed. The physical and cognitive improvement, along with balance improvement as in these studies, are indicative of the potential of Nordic walking as a therapeutic intervention.

To Nordic walking, proper technique training is indispensable for safety and maximum effectiveness. Nordic walking can optimise improvements in balance and functional mobility when they are integrated with other essential, such as resistance training or physiotherapy. (Linhares et al.2022.) According to studies by Peyré-Tartaruga et al.

(2022) and Linhares et al. (2022), Nordic walking is accessible and easy to implement, and hence it is an effective choice of exercise for older populations, contributing to long-term physical health and functional independence.

## 2 Theoretical background

Balance is a vital component of mobility and independence, in elderly women, because physiological changes related to aging that commonly cause its deterioration. The factors contributing to deterioration in balance are reduced muscle strength, joint instability, sensory impairment, and hormonal changes that go along with menopause. (Piotrowska et al. 2020; Linhares et al. 2022.) The decline in balance increases the fall risk which is the common source of injury (Haas et al. 2024). Falls trigger a snowball effect of negative consequences, such as physical injuries, loss of autonomy and increased fear of falling, which decreases physical activity and impairs balance (Salbach et al. 2024: 53-31). Nordic walking is a mode of exercise with poles activating both the upper and lower muscles of the body adding support on the body along with enhancing body stability. Nordic walking is unlike regular walking, minimising the risk of falls related to gait pattern and posture by increasing the general muscle strength of the body. (Piotrowska et al. 2020; Encarnación-Martínez et al. 2023: 35-40.)

Nordic walking has functional, psychological and cognitive benefits in fall prevention (Piotrowska et al. 2020; Grigoletto et al. 2022; McCracken et al. 2021). According to Morano et al. (2024), Nordic walking enhances reaction times and cognitive processing, improving mental health and decreasing symptoms of anxiety and depression. The decreased muscle mass, reduced joint flexibility, and alterations related to menopause make the aging female population physiologically and hormonally more prone to balance and fall issues regarding balance. Hass et al. (2024) have pointed out that one third of adults aged 65 and over experience falls every year, and imposes physical, psychological and economic burdens. The fear of falling causes decreases in activities and increases in time of recovery after falls and fractures, as well as social isolation, promoting to changing the quality of life (Linhares et al. 2022).

Nordic walking also associates with enhanced mental health. The rhythmic movement involved in Nordic walking along with the cognitive and physical engagement, has been found to lower stress levels and improve mood. (Morano et al. 2024:222.) Nordic walking's low-impact nature and accessibility make option for older women to engage in more intense forms of exercise (Peyré-Tartaruga et al. 2022).

Ground reaction forces (GRF) and Margins of stability (MOS) have been of help to explain how the use of poles during walking can redistribute forces and improve overall stability (Peyré-Tartaruga et al. 2022). Nordic walking has been linked to improvements in gait patterns and postural alignment, which are crucial for fall prevention (Encarnación-Martínez et al. 2023: 35-40; Morano et al. 2024:222).

Leal-Nascimento et al. (2022) and Szeffler-Derela et al. (2020), highlighted that Nordic walking provides physical health benefits such as an improvement in cognitive activities, anxiety reduction and even beneficial effects on reaction times. Nordic walking provides psychological benefits for elderly women suffering from problems due to disengagement issues, aging processes and bodily pressures. Nordic walking can act as a comprehensive solution for physiological function and cognitive wellbeing among women due to its potential as a rehabilitation tool has been studied in neurodegenerative conditions such as Parkinson's disease and dementia.

Studies by Piotrowska et al. (2020) and Marciniak et al. (2020), highlight improvements in functional fitness and balance achieved through Nordic walking sessions. Nordic walking represents an intervention toward improvement in balance focusing on musculature, cognitive function and psychological that have been showing immense potential for encouraging physical independence and the well-being in elderly individuals. Nordic walking has efficacy in managing with both physical and psychological health issues. (Tschentscher et al. 2016: 76–84.)

Salbach et al. (2024), demonstrated the case of structured outdoor mobility programs for example, the GO-OUT program is effective in improving walking capacity and self-efficacy among older adults both crucial components in enhancing balance. Nordic walking prevails mobility, balance and health in general among older adults. The program model illustrates that for outdoor walking both the personal factors of walking capacity and self-efficacy interact with external influences like the access of neighbourhoods.

Strength training and flexibility have been long recognised for their positive effects on balance (Salbach et al.2024: 53-31; Marciniak et al. 2020). Salbach et al. (2024), showed that group walking programs including Nordic walking, improved gait speed and lower body strength, both essential for maintaining balance. For older adults, particularly those with osteoporosis or musculoskeletal impairments, improvements in bal-

ance are essential for reducing the risk of falls and enhancing overall mobility. The addition of poles in Nordic walking further enhances coordination and stability by engaging the upper body contributing to better overall balance (Marciniak et al. 2020).

Biomechanics also plays a significant role in understanding how Nordic walking improves balance (Leal-Nascimento et al. 2022: 290-297). The use of poles in Nordic walking minimises joint stress while improving walking efficiency and posture. The inclusion of both upper and lower limbs during Nordic walking provides posture correction, increased stride length and gait mechanics, all of which improve balance. Nordic walking makes movement less energy consuming, not as tiresome as it usually is and benefits the elderly who would face challenges while walking. (Encarnación-Martínez et al.2023: 35-40; Leal-Nascimento et al. 2022: 290-297.)

The cardiovascular benefits of Nordic walking promote balance (Grigoletto et al. 2022; Wiacek et al.2023: 865–870). As reported by Peyré-Tartaruga et al. (2022), as a form of aerobic exercise, Nordic walking boost cardiovascular function and improves blood flow while reducing blood pressure. Cardiovascular fitness is crucial in relation to the energy levels individuals need to handle daily physical activities including walking. Improved circulation also facilitates muscle and joint flexibility for better balance. The inclusion of resistant shock absorbers as an indicator of autonomic nervous system activity may provide a better understanding of how the body tailors to exercise than with classic poles. (Wiacek et al. 2023: 865–870; Marciniak et al. 2020.) As demonstrated by Marciniak et al. (2020), improvements in resistant shock absorbers, exhibit better autonomic control and overall resilience than classic poles, further supporting balance.

Nordic walking, as a weight-bearing exercise, has been beneficial in improving bone density and preventing the progression of osteoporosis, which is important in maintaining balance (Linhares et al.2022). According to Leal-Nascimento et al. (2022), varied terrain, like uphill walking, provides greater mechanical loading on the bones, which is necessary for the enhancement of bone strength. Mechanical loading is very essential for older women because they have a bigger risk of osteoporosis and fractures. Salbach et al. (2024), displayed that task-oriented training in natural environments with Nordic walking, improved sensory feedback and proprioception are all factors necessary to sustain balance. Nordic walking accommodates variations in terrain and uphill walking to further challenge the person and improve balance control. Nordic walking can strengthen muscle, improve bone density, contributing to better balance control. Therapeutic effect of Nordic walking on balance is significant with the poles stabilize

the upper body, improving posture, while the coordination of both arms and legs enhances balance.

Studies by Peyré-Tartaruga et al. (2022) and Salbach et al. (2024), have shown Nordic walking to positively impact general health parameters such as blood pressure, strength, flexibility, and overall fitness making it a comprehensive intervention for older adults. Regular Nordic walking enhances cardiorespiratory endurance, muscular strength, postural stability, gait efficiency, functional mobility and proprioceptive feedback, overall health and mobility. By targeting various health domains, including cardiovascular, musculoskeletal, cognitive and biomechanical factors, Nordic walking offers a complete intervention that promotes balance and stability in older women. Thus, enhances physical function but also reduces the risk of chronic health conditions and falls, contributing to improved quality of life in this population. (Grigoletto et al. 2022.)

## 2.1 Balance and mobility in women

Balance and mobility are critical in maintaining an active independent lifestyle. Physiological changes associated with aging, such as sarcopenia, reduced flexibility, and slowed reaction times, make balance more challenging. In women, these changes often occur earlier than men in their menstruating phase and progress more rapidly due to menopause, which affects both bone density and muscle mass. (Piotrowska et al. 2020.) Good balance depends upon the combination of sensory input, neural control, and muscle function. When balance weakens, the risk of falling rises, which is the common cause of injury among older adults, particularly women. Mobility, described as the regular activities of walking and climbing stairs, also declines with the advancement of age. When these abilities are lost, they may result in frailty and dependence. (Nemoto et al. 2021: 209-215.) In a study by Piotrowska et al. (2020), it was said that balance and mobility are at the very core of healthy aging. The component of mobility is important in enabling safe and effective locomotion.

In women, hormonal changes, weaker muscles and less stable joints contribute to declining balance and mobility with age. Menopause has a strong impact on it. (Linhares et al. 2022.) Lower estrogen levels significantly contribute to increased risk factors, including reduced bone strength and weakened muscles. The changes in bone strength and weakened muscles in turn impair proprioception, the body's ability to sense its position and movement which is essential for maintaining balance. (Wochna et al. 2022.) Sarcopenia, age-related muscle loss, impact women harder leaving their

legs weaker and joints less stable. External elements additionally contribute to the situation. Slippery floors, uneven floors, or insufficient lighting increase the risk of falling. Fear of falling often keeps people from moving which makes the problem even worse. (Haas et al. 2024.)

## 2.2 Contributing factors to balance deficits and fall incidence in women

Common contributors of diminishing balance include muscle weakness, joint stiffness, and reduced flexibility. (Piotrowska et al.2020.) The prevalence of osteoporosis in women elevates the risk of falls by rendering bones and joints more susceptible to fragility (Linhares et al.2022). Hormonal changes that occur during menopause adversely influence both bone density and muscle strength, exacerbating balance difficulties. Cognitive impairment and depressive symptoms are important contributing factors, as they can slow reaction times and impair coordination. (Morano et al.2024: 222.)

Muscle loss is common among older women, especially after menopause (Wochna et al. 2022). About one third of women have sarcopenia resulting in the weakening of the body lower parts and increasing the probability of falls (Linhares et al.2022). Aging affects three domains that are crucial to balance which are visual acuity, vestibular function of the inner ear, and proprioceptive feedback from the feet. Such declines due to aging compromise one's ability to adjust balance in a proper way against external perturbations or unexpected changes. (Salbach et al.2024: 53-31.) Health conditions like arthritis and osteoporosis restrict mobility and increase the risk of falls (Piotrowska et al. 2020). Following a fall, many women reduce their activity levels due to fear, which further causes decline in strength and balance creating a cycle of reduced mobility and increased fall risk (Encarnación-Martínez et al. 2023:35-40).

## 2.3 Prevalence of balance problems and falls

Falls are among the most significant contributors to health related risks and complications experienced by women in old age, with almost 30% of adults above 65 years falling at least once a year. Women are most susceptible because they have gender-related health issues such as lower bone density and muscular strength, which increase the danger of falls and injuries associated with them. (Piotrowska et al.2020.) It is estimated that 35% of women in the age group of 64-93 years face substantial balance issues, a critical factor contributing to their elevated fall risk (Salbach et al.2024: 53-31). By their 80s, half of all the women experience a fall annually (Nemoto et al.2021: 209-

215). Falls often result in severe injuries and may even require hospitalisation particularly among those suffering from osteoporosis (Linhares et al.2022). Balance related problems are common in women of the geriatric population. Falling often leads to injuries such as fractures or other long-term incapacities. The repercussions involve a need for continued care, a loss of independence, or deterioration in quality of life. Falls put a considerable economic burden on healthcare systems, with costs rising to billions of dollars each year. (Haas et al.2024.)

## 2.4 Current Interventions to improve balance

Tai Chi has been shown to significantly decrease the risk of falls in older adults and developing good posture and body awareness. Tai Chi is special because of its smooth, fluid movements that improve balance and flexibility. (Tschentscher et al. 2016:76 – 84.) Aerobic exercise, such as walking, plays a significant role in health, strengthening the cardiovascular system and muscles, that are necessary to maintain balance (Wiacek et al.2023).

Exercises that help improve balance and reduce fall risk include resistance exercise that strengthens the muscles in the legs which provide stability but might not contain all the movements required for balance in everyday life (Pellegrini et al. 2022).Yoga improves flexibility and core strength but may not always provide the dynamic movements necessary to carry out functional balance activities (Encarnación-Martínez et al. 2023).

## 2.5 Characteristics of Nordic walking

Nordic walking encompasses the utilisation of poles while ambulation. Nordic walking activity drew inspiration from cross country skiing and engages up to 90% of muscle groups that enhances muscular strength, promotes cardiovascular health, and facilitates more stable movement. (Baggish 2022.) The incorporation of poles diminishes the stress placed on joints, making it particularly beneficial for individuals suffering from arthritis or comparable ailments (Encarnación-Martínez et al. 2023: 35-40). Nordic walking is inexpensive and can be easily practiced, making it a good option for those who might not have access to resources such as gym facilities or costly equipment (Tschentscher et al. 2016: 76-84).

## 2.6 Nordic walking and balance

There is a strong involvement of Nordic walking in enhancing balance, especially in women (Linhares et al.2022). A study by Piotrowska et al. (2020), describes that Nordic walking is strongly associated with improved gait and a reduced falling incidence among elderly women. Marciniak et al. (2020), draw a conclusion that Nordic walking strengthens the upper and lower extremities, thereby tending to improve balance. Studies by Nemoto et al. (2021) and Linhares et al. (2024), found that Nordic walking improves posture and muscular strength, which specifically benefits women suffering from osteoporosis compared to regular walking. Unlike regular walking, Nordic walking promotes added cardiovascular and neuromuscular advantages. (Nemoto et al. 2021: 209-215; Linhares et al. 2024; Wiacek et al. 2023.) Nordic walking emphasised mental benefits such as improved reaction time and motor coordination, contributing to a lower risk of falling (Wiacek et al. 2023: 865-870). Nordic walking is a way to promote physiological health not only physical but also cognitive in the elderly and it is a feasible effective intervention to enhance balance and mobility (Tschentscher et al. 2016: 76-84).

## 3 Aim and data collection

The aim of the literature review was to study the impact of Nordic walking on balance in women.

Table 1. Inclusion and Exclusion criteria implemented for the data collection process

	Inclusion	Exclusion
Publication Date	Articles within the period of 2019-2024.	Articles published before the year 2019.
Content Studies	Nordic walking, pole walking, balance, women.	Studies that do not concern Nordic walking, pole walking, balance, women.
Study Design	All types of study methods and reviews.	N/A
Language	Articles in English.	Not published in English.

Materials for this review were obtained by systematically searching databases, including PubMed, CINAHL Complete (Ebsco), ProQuest Central, Wiley Online Library, and

Sage Journals. Initial searches of these databases were conducted along with refining the search terms that enhanced the relevance of the searches. Searches conducted in October of 2024 and December 2024 were conducted using search terms such as Nordic walking, pole walking, balance, women, and female adding in a publication filter of 2019-2024. The time applied was to yield the most recent published studies about Nordic walking. Figure 1 summarises the results of each database search.

The inclusion and exclusion criteria in Table 1, ensure the quality of the review, and hence consider only relevant studies. The search was specified to English language publications only and excluded publications in other languages. Following the search, the publication years and the headlines of studies were manually screened to identify irrelevant articles.

For example, in PubMed, the search words were "Nordic walking" OR "pole walking" AND balance AND women, "Nordic walking" OR "pole walking" AND balance AND female. The results were filtered from 2019 to 2024 and scanning study headlines for unrelated studies. The same process was carried out in CINAHL Complete (Ebsco), ProQuest Central, Wiley Online Library, and SAGE Journals. The search for each database was carried out using similar search words and Boolean operators. The publication year was applied to filter the search results, and irrelevant articles were excluded based on headline screening. The studies from all databases were arranged in an Excel sheet to check for duplicates. After eliminating the duplicates, the abstracts of the remaining articles were reviewed, and irrelevant articles were excluded further. Information from each study on items including a list of authors, year of publication, aim of the research, description of the intervention, target populations, number of sessions and their frequency, intensity, equipment used, and the outcomes were addressed. The results of the full text articles were reviewed for this literature review.

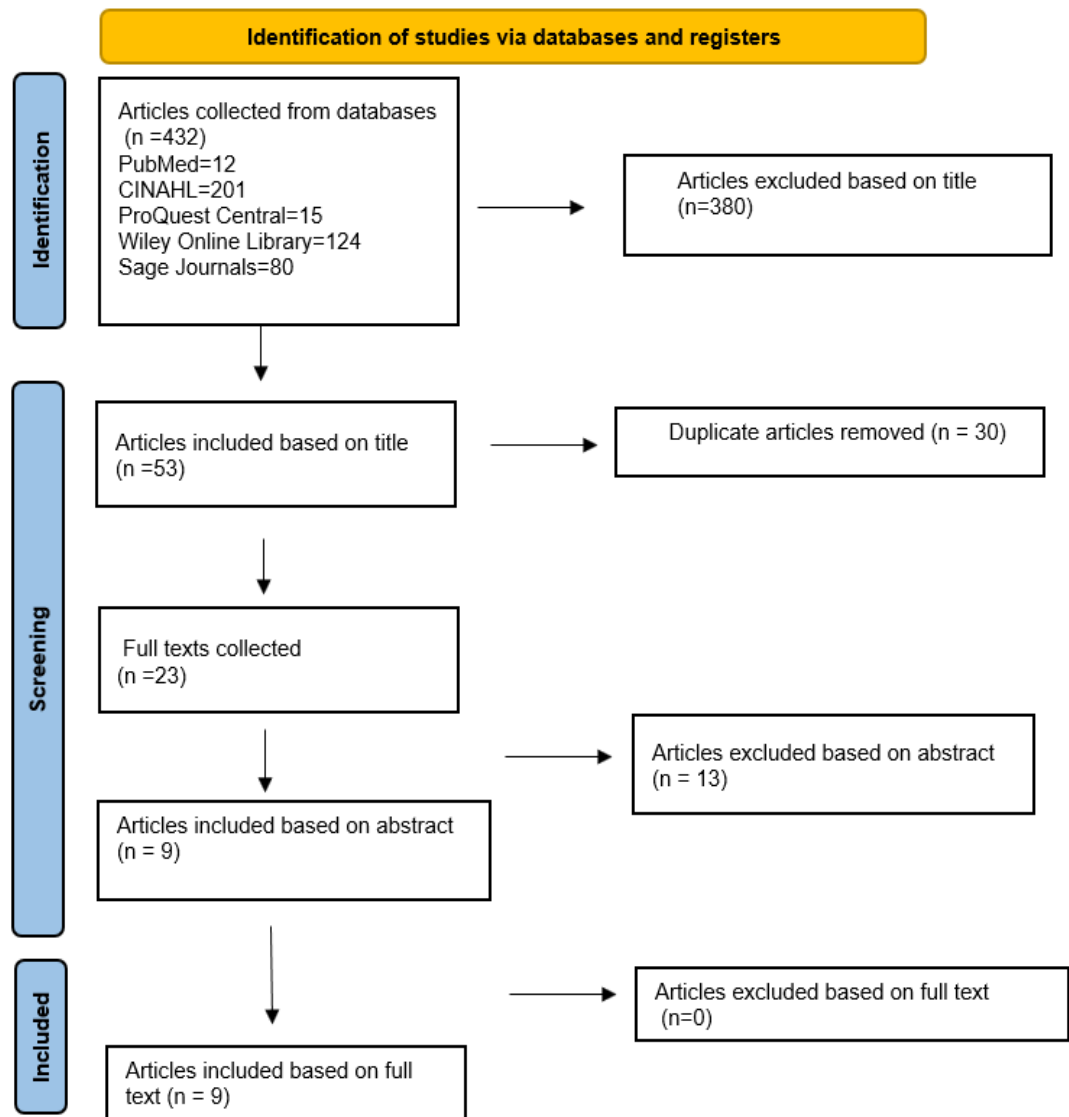


Figure 1. Flowchart of the review.

## 4 Results

Of the 432 records identified, 30 were duplicates which were excluded. 380 were excluded after headline screening, unavailability, or irrelevance leaving 53 studies to be reviewed. 23 full-text articles were evaluated. 13 were excluded due to abstract ineligibility. Finally, 9 studies were included for this review on abstract eligibility and full text eligibility.

Authors and Year and Place	Purpose of Study	Methods	Participants	Intervention	Results and Conclusion
Wiacek, M., Natora, J., Zubrzycki, I. Z., & Tomasiuk, R. (2023), Germany	To analyse the effects walking and Nordic walking programs on middle aged women.	Quasi experimental, interventional study.	Women in between the ages of 52 to 55 years were recruited through advertisements. There were 50 women in each test group.	It was a 12 week supervised walking and Nordic walking program. The parameters that were measured in the exercise program were maximum oxygen uptake, fat tissue percentage, systolic blood pressure, body muscle tissue percentage, diastolic blood pressure, resting pulse. The program consisted of three 90 minutes exercise sessions per week. The subjects were assigned randomly to the walking or Nordic walking group. All the parameters were measured one day before and after the program.	Both walking and Nordic walking improved physical fitness. No significant superiority of Nordic walking over walking was found. In summary, walking and Nordic walking can be interchanged to enhance cardiovascular health, neuromuscular health and cardiorespiratory endurance that contributes to better balance.
Wochna, K., Ogurkowska, M., Leszczyński, P., Stemplewski, R., Huta-Osiecka, A., Błaszczak, A., Mączyński, J., & Nowak, A. (2022), Poland.	To assess the effects of Nordic walking using resistant shock absorber poles on femur bone density strength in postmenopausal women.	Experimental study	Postmenopausal women were divided into Nordic walking and Nordic walking with resistance shock absorption poles groups. The participants of the program were selected by placing advertisements in local press and in information happenings. Women in age group of 60 years	The study consisted of eight weeks of training, 16 training sessions, for twice a week, with Nordic walking either with classic traditional Nordic walking poles or resistant shock absorber poles. Women from the resistant shock absorbers group were using poles having resistant shock absorbers combined with a stretch resistance of four kg.	The study concluded resistant shock absorber poles significantly improved the femur bone density strength compared to classic traditional Nordic walking poles, thus being beneficial for musculoskeletal health in strengthening the muscles used for balance and stability. Nordic walking with resistant shock absorbers may be replacement to exercise with classic traditional Nordic walking or to walking, especially who want to engage the muscle strength to improve balance and coordination. Despite the asymmetry in muscle parameters during use of

			and above were part of the study. From 25 women ,ten were in resistant shock absorber group; 15 were in Nordic walking group. Statistical analyses were conducted on ages 61 to 75 years.		resistant shock absorber poles, this may indicate the need for structured control of gait technique to prevent the effects of asymmetry in the lower back.
Marciniak, K., Maciaszek, J., Cyma-Wejchenig, M., Szeklicki, R., Maćkowiak, Z., Sadowska, D., & Stemplewski, R. (2020), Poland.	To investigate the effect of Nordic walking with resistance absorber poles on functional health in women in 60 years and older.	Interventional study	Women over 60 years of age Participated in the program. 47 women were divided into groups for the study program. Experimental group (EG) was Nordic walking with resistance-absorber poles and control group (CG) was Nordic walking with traditional Nordic walking poles.	The groups trained at the simultaneously, for eight weeks, twice a week, for 16 sessions. Women from the control group used traditional Nordic walking poles, while the experimental group used Nordic walking poles which had a built-in resistant shock absorber having stretch resistance of four kg.	The study showed functional health improvement in both study participants. Resistant shock absorber poles improved balance by enhancing aerobic endurance and muscle strength more than classic traditional Nordic walking poles, showing benefits for older adults. Nordic walking combined with resistant shock absorber poles helps improve balance by activating upper body strength and total endurance. People using resistant shock absorber poles did more work than those using classic traditional Nordic walking poles. Using resistant shock

			They were selected by placing advertisements on social platforms such as the local papers and the website.		absorber poles with Nordic walking are likely to enable optimal work intensity and balance stability through muscle activation during training in older women.
Piotrowska, J., Guskowska, M., Leś, A., & Rutkowska, I. (2020), Poland.	To assess the impact of Nordic walking and cognitive training (CT) on fitness and balance in older adults.	Experimental study.	Residents of elderly care centres, aged 60 years and older, with average health and cognitive abilities were the subjects in the study.	Nordic walking sessions alone or combined with cognitive training were compared to a non-intervention control group. There were two experimental groups of Nordic walking and cognitive training, and the second group only in Nordic walking sessions, and the control group without interventions. Duration of protocol was for 60 minutes for three months, for twice a week.	The experimental groups, Nordic walking and cognitive training with Nordic walking improved functional fitness and balance. Nordic walking with cognitive training providing additional cognitive benefits to improve balance. The Nordic walking for older adults guided by professionals can be an effective program to develop functional fitness and to improve balance for stability.

<p>Fischetti, F., Greco, G., Toselli, S., Mauro, M., Oppio, A., Cataldi, S., Grigoletto, A. (2022), Italy.</p>	<p>To study the effects of Nordic walking on measurements of anthropometry, body composition, and functional abilities in middle-aged adults.</p>	<p>Interventional study.</p>	<p>There were 77 participants, 56 women and 21 men who were a part of the study program, with mean age of 57 years, from a Venice Nordic walking society.</p>	<p>The program had three months of Nordic walking training, two times a week, for 1 hour. The session included warm up, main walking, and cool-down.</p>	<p>The result had significant changes in functional parameters that support balance by ensuring better control and stability during Nordic walking. Stress and anxiety also decreased improving balance by reducing muscle tension and improving focus and coordination. Nordic walking increased lower body strength, contributing to better stability and balance during walking. Nordic walking also influenced changes in body composition that help improve muscle quality for coordination.</p>
<p>Nemoto, Y., Sakurai, R., Ogawa, S., Maruo, K., &amp; Fujiwara, Y. (2021), Japan.</p>	<p>To evaluate the impact of unsupervised Nordic walking on cognitive and physical function in older volunteer women.</p>	<p>Cohort study.</p>	<p>47 women were assigned to three groups, 19 in Nordic walking, 19 in walking and 12 in control groups.</p>	<p>Nordic walking and walking groups exercised weekly, Nordic walking group trained with poles for three months. Cognitive functional measurement included the trail making test and the Montreal cognition assessment MoCA-J, 23 test. Physical function assessment had timed up and go test, functional assessment, five meters walk test, single leg balance test and hand strength.</p>	<p>Nordic walking significantly improved cognition and physical function enhancing stability. Nordic walking improved walking speed more than walking enhancing coordination and balance, reducing the risk of falls.</p>

<p>McCracken, S., Logan, P., Anthony, K., &amp; Parr, J. (2021). Nottingham UK.</p>	<p>To explore barriers, benefits, and feasibility of Nordic walking with Parkinson's disease.</p>	<p>Qualitative study.</p>	<p>Nine people with Parkinson's disease with mean age 62 years, including three women and six men participated in the study.</p>	<p>The study had eight weeks of Nordic walking sessions that had guided practice at a university facility.</p>	<p>Nordic walking improved lower body mobility which are crucial for maintaining balance and move more confidently and steadily. The patients enjoyed this activity and thus supported its integration into the National health service programs for people with Parkinson's disease reducing the risk of falls and better quality of life.</p>
<p>Szeffler-Derela, J., Arkuszewski, M., Knapik, A., Wasiuk-Zowada, D., Gorzkowska, A., &amp; Krzystanek, E. (2020), Poland.</p>	<p>To compare the effects of Nordic walking versus standard rehabilitation on Parkinson's disease symptoms.</p>	<p>Randomized controlled trial (RCT).</p>	<p>40 Parkinson's disease patients, mean age 64 years, were part of the exercise program.</p>	<p>Nordic walking group received supervised outdoor sessions. Standard rehabilitation group received traditional indoor rehabilitation exercises. Recruited people were randomly assigned two groups, Nordic walking or standard rehabilitation. For six weeks, 12 rehabilitation sessions were conducted twice a week. Nordic walking group session, monitored by a physiotherapist was conducted outside in a park. Exercise program lasted for 90 minutes. Individual standard rehabilitation session, supervised by a physiotherapist, was held inside in the facility. Standard rehabilitation program, were for 45 minutes and consisted of exercises that were individually tailored at improving high amplitude movements, gross and fine</p>	<p>Nordic walking showed greater motor improvement, gait quality and balance control than standard rehabilitation. Both improved quality of life significantly associating balance and physical function.</p>

				motor skills stretching, activity for balance, flexibility, muscle strength, gait, and transfers.	
Soboleva, A. A., Iskakova, G. S., Khasanova, R. R., Andreev, V. I., & Zagrevsky, O. I. (2016). Russia.	To analyse the impact of Nordic walking on the social health of women aged 50 to 60 years.	Observational study	Women aged 50 to 60 years were the participants of the study.	Nordic walking training sessions focused on physical and psychosocial engagement. A SF-36 questionnaire that assessed well-being and satisfaction, along with the percentage of factors influencing health status.	Nordic walking improved social well-being by fostering connections and reducing isolation. All the women rated their health and physical function as optimal compared to their initial assessment. Women who participated in the training sessions noticed increased efficiency, improved mood, greater cheerfulness, sound sleep, normalized blood pressure, and a weight loss of three to five kilograms. The training resulted in a significant enhancement in the physical health outcomes among the women in maintaining balance during dynamic movements. Besides, the women have additional performance in covering the distance of 500 to 600 meters preventing falls for better stability.

Table 2. The results of the review articles.

The authors Wiacek et al. (2023), analysed the effects of walking and Nordic walking for twelve weeks on 52 and 55 years middle aged women. maximum oxygen uptake, fat tissue percentage, systolic blood pressure, diastolic blood pressure, body mass, muscle tissue percentage, resting pulse were the parameters measured at the start and end of the exercise program. The physiological parameters as a function of the preparation period were calculated by analysis. The changes for participants which were in the walking and Nordic walking were analysed with the reliable change index. The changes in both groups improved physical fitness variables, including body mass, body composition, fat and muscle tissue percentage, blood pressure, pulse, maximum volume of oxygen. There was no significant difference in the Nordic walking group than the regular walking group. The health markers that include cardiovascular health, body composition, muscle strength and endurance, flexibility, metabolic health, and mental well-being, improved all of which contribute to better balance. Nordic walking might be an effective way towards fitness for middle aged women, but it does not illustrate major advantage over standard walking in terms of the health benefits of cardiovascular, neuromuscular and cardiorespiratory. (Wiacek et al. 2023: 865–870.)

Wochna et al. (2022), investigated the impact of Nordic walking using resistant shock absorbers poles on femur bone density strength in postmenopausal women. There were 25 women in two training groups. Ten subjects were using resistant shock absorbers, and 15 subjects were using Nordic walking poles, in eight weeks of training program. The forearm, hip and spinal bone mineral density, shoulder and elbow joints, torques of flexors and extensors were measured in the training programs. The difference was largely in the femur bone density strength index, in the elbow with the ratio of the flexors to extensors, in the shoulder joints and flexors in the shoulder joint for the left arm. The study found that Nordic walking with resistant shock absorbers poles for postmenopausal women led to beneficial changes in the femur bone density strength index, thus being beneficial for musculoskeletal health in strengthening the muscles used for balance and stability. No major influence on bone mineral density values measured of the whole body, the hip, forearm and lower back regions. Asymmetry in of muscle parameters that were observed using resistant shock absorbers poles, may indicate the need for structured control of the gait technique to prevent consequences of asymmetry of the lower back spine. They discovered that resistant shock absorbers poles could enhance femur bone density strength in comparison with the usual Nordic walking poles. The findings are of special importance, considering that it has been

demonstrated that greater risks of osteoporosis fracture in women after menopause. (Wochna et al. 2022.)

The study by Marciniak et al. (2020), examined on functional fitness of elderly women with resistant shock absorbers poles during Nordic walking. The purpose of the assessment was to determine the effects of Nordic walking with poles combined with a resistance shock absorber on functional fitness of older women. Participants were assigned to experimental group using poles combined with resistance shock absorber or the control active group using classic traditional Nordic walking poles. Functional fitness was measured with the Senior fitness test pre and post intervention that was for eight weeks, two times a week for 75 minutes. 42 women, mean age 64 years and older were assigned to the experimental group training with poles combined with resistance shock. Interaction reported significant aerobic endurance and the strength of upper body, with improvement in the experimental group. In contrast to the classic traditional Nordic walking poles, work with resistant shock absorbers poles showed better improvement in balance by enhancing of muscular strength and aerobic endurance. (Marciniak et al. 2020.)

Piotrowska et al. (2020), have assessed cognitive training to Nordic walking to evaluate its effect on older people for fitness, balance and mental function. The groups of subjects who performed only Nordic walking or those who combined Nordic walking with cognitive training both improved their balance and fitness. The evaluation involved 61 women aged 64 to 93 years residing in elder day care centres. 20 individuals underwent a three month program with Nordic walking and cognitive training, 20 people participated only in Nordic walking classes and 21 were assigned to the control group. The control group did not undergo any interventions. The Romberg balance test, Fullerton functional fitness test, and attention perceptivity test were applied following the intervention. An increased balance duration during single leg stance with eyes open, both on the left and right leg was observed in Nordic walking with cognitive training groups and with Nordic walking alone. It highlighted how such a combination of physical and mental exercises improve balance for stability and the overall wellbeing of an individual. (Piotrowska et al. 2020.)

Fischetti et al. (2022), investigated changes in body composition and perceived level of stress after three months of regular practice in Nordic walking. The study followed a pretest and post-test design with 77 participants, of which 21 were men and 56 were

women. They underwent two 60 minutes Nordic walking sessions each week for three consecutive months. Measurements included anthropometric characteristics, body composition by bioelectrical impedance analysis, and physical tests such as handgrip strength and six minute walk tests. Two Nordic walking training sessions per week were performed by the participants, which included a warmup, main walking activity, and cool-down stretches. After the intervention, body fat parameters were significantly reduced and lower body strength was increased, especially in women contributing to better stability and balance during walking. The level of perceived stress and anxiety in participants were reduced, indicating positive implications for role of Nordic walking on physical and psychological health in the middle age population improving balance by reducing muscle tension and improving focus and coordination. Nordic walking was recommended for accessible exercise that maintains health. It was possible to reveal a great reduction of body fat while strength was notably gained more among women that help improve muscle quality for coordination. (Fischetti et al.2022.)

Nemoto et al. (2021), research investigated the effect of Nordic walking on cognition and physical functions in a female older adult population. 47 women aged 70 years and older were into three groups, 16 in Nordic walking, 19 in walking, 12 in control group. The Montreal cognitive assessment (MoCA-J), Trail making test, physical health, hand strength, walking speed, balance ability, timed up and go test and functional capacity were evaluated in the program. Nordic walking significantly improved cognition and physical function, enhancing stability. Nordic walking also improved walking speed more than regular walking, which enhanced coordination and balance, reducing the risk of falls. ( Nemoto et al. 2021.)

A study by McCracken et al. (2021), included patients with Parkinson's disease and measured the effects of Nordic walking on mobility and quality of life. People with Parkinson disease joined an eight week Nordic walking programme. Measures of mobility Timed up and go, ten metre walk test, quality of life and Parkinson disease questionnaire were recorded pre and post intervention. The analysis indicated that Nordic walking is superior to walking in improving postural stability and gait. Participants slept better, managed their pain, constipation, mood, exercising outside post intervention. Participants, with Parkinson's disease, enjoyed the sessions and experienced improvements in mobility, balance, and quality of life. This demonstrates that Nordic walking is a feasible and beneficial form of exercise, enhancing physical

health reducing the risk of falls, providing emotional benefits and better quality of life. (McCracken et al.2021:193-202.)

Szeffler-Derela et al. (2020), compare the effects of Nordic walking and standard rehabilitation on symptoms in patients with Parkinson's disease. The investigation aimed to establish whether Nordic walking training can be used to manage the motor impairment of Parkinson's disease patients. 40 patients with Parkinson's disease mean age 64 years, ranging between 50 to 75 years, in Hoehn and Yahr stages II–III, were randomized into Nordic walking or standard rehabilitation (SR) programs. 12 rehabilitation sessions were performed twice a week over six weeks period. The median unified Parkinson's disease rating scale, gait quality and balance control, quality of life, assessed by the Parkinson's disease questionnaire were significantly lower with Nordic walking than with standard rehabilitation. Nordic walking over a period of six weeks is effective in improving functional performance, balance, the quality of gait, and quality of life in patients with Parkinson's disease, and its effectiveness is comparable to that of standard rehabilitation. (Szeffler-Derela,et al.2020:356.)

Soboleva et al. (2016), explored how Nordic walking affected the social well-being of women aged 50 to 60 years. The were categorised into three groups depending on the level of their functional capacity and readiness into low, average, and high. The program involved the measurement of physical readiness by aerobic endurance using the Cooper test and then divided the subjects into three groups. Nordic walking training program was implemented in a systematic manner, targeting heart rate and distance for each group. During winter, the Nordic walking training was three times each week, consisted of varying walking distance and target heart rate to an individual participant with varied fitness levels. After the intervention, all subjects reported significant improvements in health status, physical functioning improving balance, mood, and overall well-being. The study concluded that Nordic walking effectively enhances physical fitness and social well-being among women in this age group, addressing issues such as high blood pressure, excess weight, and sedentary lifestyle that helps in maintaining balance during dynamic movements preventing falls for better stability. The results showed that Nordic walking helped reduce isolation and foster social connections, improving participants psychosocial engagement. This highlights how Nordic walking is not just about physical health it can also provide important mental

and social benefits, helping people feel more connected and engaged with others. (Soboleva et al.2016.)

An overview of the studies for this review is presented in Table 2. The dates of the included studies range from 2019 to 2024, with a range of designs, two randomised controlled trials, two controlled non-randomised controlled trials, one longitudinal pre and post-test design, one mixed methods study, and one observational study. The review represented 815 participants from diverse populations including middle aged women, older adults aged 60 and above, post-menopausal women, patients with osteoporosis, patients with Parkinson's disease, socially isolated female, and mixed gender populations. The reviewed targets of outcome which ranged from aspects of physical fitness and balance through to cognitive and social functioning.

## **5 Discussion**

The studies for this literature review reflect the overall benefits of Nordic walking for women in supporting balance by demonstrating positive effects upon their overall health condition, cognition and their musculoskeletal system.

Results by Wiacek et al. (2023), demonstrated that regular walking as well as Nordic walking improve key health parameters like aerobic capacity, blood pressure as well as body composition. Although Nordic walking may not surpass regular walking in terms of neuromuscular fitness, cardiovascular fitness and cardiorespiratory fitness, it offers unique advantages when training factors are tailored to an individual's health condition. These benefits include improved muscle activation, increased energy expenditure, better gait and posture, enhanced balance and stability, and positive effects on mental well-being. Both regular walking and Nordic walking were beneficial for health overall, yet there was no superiority by regular walking over Nordic walking. An initial impression that Nordic walking is superior to regular walking is altered after clinical analysis by applying the Reliable change index (RCI) test indicating no significant difference between regular walking and Nordic walking. Regular walking as well as Nordic walking can interchangeably be used at the level of neuromuscular, cardiovascular as well as cardiorespiratory health condition. (Wiacek et al. 2023.)

For postmenopausal women, Nordic walking with resisted shock absorber poles proved to be beneficial. According to Wochna et al. (2022), enhancements were found in femur strength that can significantly prevent fracture related to osteoporosis. Marciniak et al. (2020), found that there was a greater increase in functional fitness, strength and aerobic endurance in women during old age by means of specialised poles. Still, the asymmetry found by identified biomechanical parameters of muscle, means that checking the gait technique systematically should avoid the possibility of harmful effects like asymmetry of rotation of the lumbar spine. The findings indicate that Nordic walking is no ordinary cardiovascular exercise as it incorporates strength training too, so it is an effective aging intervention. Nordic walking with classic poles led to increased femur strength, indicating improved bone density, which is useful for the musculoskeletal system. (Wochna et al. 2022; Marciniak et al. 2020.)

Piotrowska et al. (2020), found that, Nordic walking when combining it with cognitive training has an enhancing effect upon the state of balance, mind functioning, and overall well-being for elders. Functional fitness increased after sixteen training sessions for training groups, yet aerobic endurance increases were greater by resistance shock absorber poles than classic poles. The findings indicated that Nordic walking by resistance shock absorber poles offered further increase in strength as well as total endurance since it loads the upper limbs greater than regular Nordic walking. The findings supported that resistance shock absorber poles can enable optimal work capacity during training, especially for women at a later stage of aging of life. (Piotrowska et al. 2020.)

In the study by Fischetti et al. (2022), regular Nordic walking practice led to reduced stress and anxiety, indicating its role in mental health support. Participants experienced significant reductions in body fat and increased lower body strength, particularly among women. Stress and anxiety levels also decreased, highlighting the psychological benefits of Nordic walking. Nemoto et al. (2021), observed enhanced gait speed in women over 70, reinforcing the idea that Nordic walking contributes to mobility and independence. The study demonstrated that Nordic walking significantly improved cognitive and physical function, example MoCA-J scores and walking speed more than standard walking. The findings indicated that Nordic walking not only maintains but actively supports cognitive health, making it a valuable intervention for aging-related conditions. (Fischetti et al. 2022; Nemoto et al. 2021.)

Research by McCracken et al. (2021), demonstrated that Nordic walking improves mobility and postural stability in patients with Parkinson's disease, yielding results comparable to standard rehabilitation. The study suggests that Nordic walking could serve as an accessible and effective alternative for managing symptoms of rigidity and tremors and enhancing the quality of life for Parkinson's patients. Participants in the Nordic walking program showed improvements in mobility and quality of life, reinforcing its potential inclusion in National health service programs for individuals with Parkinson's disease. (McCracken et al. 2021.)

Szefler-Derela et al. (2020), found that Nordic walking improves motor function in Parkinson's patients, showing greater motor improvement than standard rehabilitation. Both interventions of Nordic walking and standard rehabilitation significantly improved gait and quality of life, but Nordic walking had a more proclaimed impact on mobility and postural stability. This suggests that Nordic walking may be a superior option for improving functional performance in Parkinson's patients. (Szefler-Derela et al. 2020.)

Soboleva et al. (2016), identified the social advantages for women in age group of 50 and 60. In dealing with issues related to blood pressure levels and overweight conditions, it further identified that it stimulated people socially as well as relieved them from isolation. Participants identified remarkable changes at the level of overall wellbeing including mood, sleep level, blood pressure level becoming regular, as well as an activity level socially increased too. These findings confirm that Nordic walking is an effective exercise modality that is good for strengthening one's mind as well as their social health too. (Soboleva et al. 2016.)

The reviewed studies in this bachelor thesis confirm that Nordic walking is an effective exercise intervention for strengthening women's stability in balance, general condition level of their body and cognition level. Although it might lack significantly greater advantages than regular walking at certain levels, it has certain advantages while it uses resistive poles, improve cardiovascular, physiological, neuromuscular, respiratory aerobic endurance and cognition level. Future bachelor thesis topics could explore Nordic walking benefits through a comparing it with other balance interventions, identifying its efficacy in rehabilitation, that includes technology.

## References

- Baggish, A. 2022. Exercise and fitness. American Heart Association. June 29. <https://www.health.harvard.edu/exercise-and-fitness/fitness-trend-nordic-walking>
- Encarnación-Martínez, A., Catalá-Vilaplana, I., Aparicio, I., Sanchis-Sanchis, R., Priego-Quesada, J. I., Jimenez-Perez, I., & Pérez-Soriano, P. 2023. Does Nordic walking technique influence the ground reaction forces? *Gait & Posture*, 101, pp.35–40.
- Grigoletto, A.; Mauro, M.; Oppio, A.; Greco, G.; Fischetti, F.; Cataldi, S.; Toselli, S. Effects of Nordic Walking Training on Anthropometric, Body Composition and Functional Parameters in the Middle-Aged Population. *Int. J. Environ. Res. Public Health* 2022, 19, pp.7433
- Haas, A. N., Delabary, M. S., Passos-Monteiro, E., Wolffenbuttel, M., Donida, R. G., Casal, M. Z., Zanardi, A. P. J., Rodrigues, L. P., Martinez, F. G., & Peyré-Tartaruga, L. A. 2024. The effects of Brazilian dance, deep-water exercise and Nordic walking, pre- and post-12 weeks, on functional-motor and non-motor symptoms in trained PwPD. *Archives of Gerontology and Geriatrics*, 118, pp.105285.
- Leal-Nascimento, A. H., Soares da Silva, E., Zanardi, A. P. J., Ivaniski-Mello, A., Passos-Monteiro, E., Martinez, F. G., de Carvalho, A. R., Baptista, R. R., & Peyré-Tartaruga, L. A. 2022. Biomechanical responses of Nordic walking in people with Parkinson's disease. *Scandinavian Journal of Medicine & Science in Sports*, 32(2), pp.290–297.
- Linhares, D. G., Borba-Pinheiro, C. J., Castro, J. B. P., Santos, A. O. B. D., Santos, L. L. D., Cordeiro, L. S., Drigo, A. J., Nunes, R. A. M., & Vale, R. G. S. 2022. Effects of multi-component exercise training on the health of older women with osteoporosis: A systematic review and meta-analysis. *International Journal of Environmental Research and Public Health*, 19(21), pp.14195.
- Marciniak, K; Maciaszek, J., Cyma-Wejchenig, M., Szeklicki, R., Maćkowiak, Z., Sadowska, D., & Stemplewski, R. 2020. The effect of Nordic walking training with poles with an integrated resistance shock absorber on the functional fitness of women over the age of 60. *International Journal of Environmental Research and Public Health*, 17(7), pp.2197.
- McCracken, S., Logan, P., Anthony, K., & Parr, J. 2021. Exploring the benefits and barriers to Nordic walking in people with Parkinson's disease: A feasibility study. *British Journal of Neuroscience Nursing*, 17(5), pp.193–201.
- Morano, T., Lancia, F., Di Marco, A., Viscioni, G., Bucci, I., Grossi, S., Pellegrino, R., Cugusi, L., Grassadonia, A., Manca, A., Bullo, V., Di Giminiani, R., Izzicupo, P., Di Baldassarre, A., Fusco, A., Cortis, C., Napolitano, G., & Di Blasio, A. 2024. Flexibility and strength effects of adapted Nordic walking and myofascial exercises practice in breast cancer survivors and analysis of differences. *Healthcare*, 12(2), pp.222.

Nemoto, Y., Sakurai, R., Ogawa, S., Maruo, K., & Fujiwara, Y. 2021. Effects of an unsupervised Nordic walking intervention on cognitive and physical function among older women engaging in volunteer activity. *Journal of Exercise Science & Fitness*, 19(4), pp.209–215.

Peyré-Tartaruga, L. A., Boccia, G., Martins, V. F., Zoppirolli, C., Bortolan, L., & Pellegrini, B. 2022. Margins of stability and trunk coordination during Nordic walking. *Journal of Biomechanics*, 134, pp.111001.

Piotrowska, J., Guskowska, M., Leś, A., & Rutkowska, I. 2020. Changes in the static balance of older women participating in regular Nordic walking sessions and Nordic walking combined with cognitive training. *International Journal of Environmental Research and Public Health*, 17(15), pp.5617.

Salbach, N. M., Mayo, N. E., Webber, S. C., Jones, C. A., Lix, L. M., Ripat, J., Grant, T., van Ineveld, C., Chilibeck, P. D., Romanescu, R. G., Scott, S., & Barclay, R. 2024. Short-term effects of a park-based group mobility program on increasing outdoor walking in older adults with difficulty walking outdoors: The Getting Older Adults Outdoors (GO-OUT) randomized controlled trial. *Journal of BMC Geriatrics*, 24, pp.53–31.

Soboleva, A. A., Iskakova, G. S., Khasanova, R. R., Andreev, V. I., & Zagrevsky, O. I. 2016. The impact of Nordic walking trainings on social well-being of women at the age of 50–60. *SHS Web of Conferences*, 28, pp.01097.

Szeffler-Derela, J., Arkuszewski, M., Knapik, A., Wasiuk-Zowada, D., Gorzkowska, A., & Krzystanek, E. 2020. Effectiveness of 6-week Nordic walking training on functional performance, gait quality, and quality of life in Parkinson's disease. *Medicina*, 56(7), pp.356.

Tekin, E., Ünver, F., & Yaylali, Y. T. 2023. Investigation of the effects of 8-week Nordic and traditional walking training on blood pressure in prehypertensive postmenopausal women. *Turkish Journal of Sports Medicine*, 58(3), pp. 112–117.

Tschentscher, M., Niederseer, D., & Niebauer, J. 2016. Health benefits of Nordic walking: A systematic review. *American Journal of Preventive Medicine*, 44(1), pp.76–84.

Wiacek, M., Natora, J., Zubrzycki, I. Z., & Tomasiuk, R. 2023. Physiological responses associated with Nordic walking and walking in middle-aged women. *International Journal of Sports Medicine*, 44(12), pp.865–870.

Wochna, K., Ogurkowska, M., Leszczyński, P., Stemplewski, R., Huta-Osiecka, A., Błaszczyk, A., Mączyński, J., & Nowak, A. 2022. Nordic walking with an integrated resistance shock absorber affects the femur strength and muscles torques in postmenopausal women. *Scientific Reports*, 12(1), pp. 20089

