AEROBIC EXERCISE PRESCRIPTIONS ON BONE STRENGTH AND POSTURAL STABILITY: A SCOPING REVIEW

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AEROBIC EXERCISE PRESCRIPTIONS ON BONE STRENGTH AND POSTURAL STABILITY: A SCOPING REVIEW

By

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CERTIFICATE

This is to certify that the thesis entitled “AEROBIC EXERCISE PRESCRIPTION ON BONE STRENGTH AND POSTURAL STABILITY” is the bona fide record of research work done by of research work done by Ms “SAIDATUL SHAMINE BINTI SHAKIREN” during the period from September 2020 to July 2021 under my supervision. I have read this dissertation and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis to be submitted in partial fulfilment for the degree of Bachelor of Health Science (Honours) (Exercise and Sports Science).

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DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated and duly acknowledged. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at Universiti Sains Malaysia or other institutions. I grant Universiti Sains Malaysia the right to use the dissertation for teaching, research and promotional purposes.

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"SAIDATUL SHAMINE BINTI SHAKIREN"

Date: 7 July 2021

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LIST OF SYMBOLS

μmol L^{-1}	**Micromoles** per litre
RM	Resistance maximum
%	Percentage

LIST OF ABBREVIATIONS

ACSM	American College of Sports Medicine
AD	Alzheimer disease
AHA	American Heart Association
BBS	Beg Balance Scale
BIVA	Bioelectrical impedance vector analysis
BMD	Bone mineral density
BMU	Basic multicellular unit
BW	Body weight
CNS	Central nervous system
COM	Center of mass
COP	Center of pressure
CST	Chair stand test
DXA	Dual-energy X-ray absorptiometry
ES	Equilibrium score
iTC	individualize Tai Chi
MoCA	Montreal Cognitive Assessment
MSC	Mesenchymal stem cells
MTC	Modified Tai Chi
OP	osteoporosis
OLST	One-leg Standing test

PA	Phase angle
PRT	Progressive Resistance Training
PRISMA	Preferred Reporting Items for Scoping reviews and Meta-Analyses
RPE	Rating of Perceived Exertion
Sema3A	Semaphorin 3A
Sema4D	semaphorin 4D
SFT	Senior Fitness Test
SOT	Sensory Organization Test
SFRI	Seriousness of fall-related injury
STC6FA	Simplified Tai Chi 6-form apparatus
TBD	Thai Boxing Dance
tTC	traditional Tai Chi
TUGT	Timed Up-and-Go test
TC-24	24-style Tai Chi
TW3	Tanner-Whitehouse 3 process
VAS	Visual Analogue Scale
VO_2R	Oxygen Consumption Reserve
WISE	Working to Increase Stability through Exercise
WOMAC	Western Ontario & McMaster Universities Osteoarthritis Index
6MWT	6-meter Walking test

PRESKRIPSI LATIHAN AEROBIK UNTUK KEKUATAN TULANG DAN KESTABILAN POSTUR: SEBUAH KAJIAN SKOP

Abstrak

Pengenalan – Senaman aerobik umumnya bermanfaat untuk meningkatkan kadar denyutan jantung, volum strok dan meningkatkan kecergasan fizikal individu.

Objektif: Kajian ini bertujuan untuk menjelaskan penemuan mengenai kesan latihan aerobik khususnya untuk kekuatan tulang dan meningkatkan kestabilan postur badan.

Metodologi – Literatur telah dicari secara sistematik berdasarkan panduan alir PRISMA, menggunakan pangkalan data PubMed, Science Direct, Scopus dan Springer Link dari tahun 2016 hingga 2021. Kesemua 15 kajian melibatkan manusia yang dikendalikan secara rawak dimasukkan dalam analisis akhir. Daripada 15 kajian hanya tiga sahaja kajian dikenalpasti mengkaji kesan latihan aerobik terhadap kekuatan tulang dan kestabilan postur secara serentak. Manakala, hanya satu kajian yang dilaporkan mempunyai kesan latihan aerobik pada kekuatan tulang sahaja, sementara 11 lagi kajian lain melaporkan peningkatan kestabilan postur. Jenis latihan aerobik termasuk latihan berjalan kaki (misalnya berjalan pantas), tarian tinju Thai, terapi latihan akuatik (latihan berasaskan air), latihan ketahanan dan kekuatan, latihan penstabilan dan juga beberapa jenis latihan Tai Chi. Berdasarkan analisis, sekitar empat kajian melaporkan bahawa senaman aerobik secara tidak langsung meningkatkan kekuatan otot selain daripada kekuatan tulang sementara lima kajian melaporkan peningkatan untuk mengurangkan risiko jatuh dan mengelakkan kecederaan yang berkaitan dengan jatuh. Oleh itu, jenis

senaman yang sesuai untuk individu yang sihat ialah satu set latihan gabungan yang terdiri daripada unsur-unsur latihan kekuatan, keseimbangan dan berjalan kaki manakala Tai Chi boleh dicadangkan untuk orang tua untuk meningkatkan kualiti hidup dan mencegah kecederaan sakit belakang. Selain itu, senaman berjalan pantas disaran untuk dilakukan oleh golongan pesakit dari mana-mana peringkat umur bagi menguatkan tulang dan meningkatkan kestabilan postur.

Kesimpulannya - Latihan aerobik lebih membantu meningkatkan kestabilan postur badan secara signifikan berbanding menguatkan kekuatan tulang di hampir semua populasi yang disasarkan. Dipercayai bahawa pembentukan tulang juga terbatas pada masalah yang berkaitan dengan penuaan seperti penurunan kepadatan mineral tulang (BMD). Pemilihan jenis senaman, jumlah masa dan kekerapan adalah penting untuk memberi kesan yang optimum kepada kesihatan individu.

AEROBIC EXERCISE PRESCRIPTIONS ON BONE STRENGTH AND POSTURAL STABILITY: A SCOPING REVIEW

Abstract

Introduction – Aerobic exercise is generally beneficial to increase heart rate, stroke volume and improving individual physical fitness.

Objective: This review aimed to clarify the findings on the effects of aerobic exercises specifically on strengthening the bone and enhancing the stability of body posture.

Methodology – Literature was searched systematically based on PRISMA guidelines, using PubMed, Science Direct, Scopus and Springer Link databases from 2016 to 2021. All 15 articles on human randomised-controlled studies - were included in the final analysis. Out of 15, only three studies were found to investigate the effects of aerobic exercise on bone strength and postural stability. Meanwhile, only one study reported the effects of aerobic exercise on bone strength alone while another 11 studies reported improvements in postural stability. Type of aerobic exercises include walking exercises (e.g. Brisk walking), Thai-boxing dance, aquatic exercise therapy (water-based exercises), resistance and strength exercises, stabilisation exercises and also few forms of Tai Chi exercises. Based on the analysis, four studies reported that aerobic exercise indirectly develops muscular strength rather than bone strength while five studies reported improvement in reducing the risk of falling and avoid fall-related injuries. Thus, the type of exercises are suitable for healthy individuals are a set of combined exercises which consists of the elements of strength, balance and walking exercises whereas Tai Chi could be prescribed for the elderly population to enhance quality of life and prevent back pain injuries. Moreover, brisk walking exercise could be recommended to be

practiced by patients from any age group in order to strengthen the bone and improve postural stability.

Conclusion – Aerobic exercises significantly promote stability in body posture in almost all population targeted rather than reinforce bone strength especially in elderly. It is believed that bone formation is also restricted in the aging-related issues such as the decline of bone mineral density (BMD). Selection of types of exercise, duration of time and frequency is essential for optimal effect for individual health.

Chapter 1

Introduction

1.1 Background of the Study

Good bone strength is described as the capacity of the bone to meet mechanical requirements. Throughout life, bone tissue is continually developed and remodeled to replace old bone with the new one. For fracture healing, bone remodeling is required, and the same goes for the homeostasis of calcium as the adaptation towards mechanical and skeleton uses (Florencio-Silva et al., 2015). The inconsistency of bone resorption and development can result in several bone diseases such as osteoporosis. It is important to have good bone strength to reduce the risk of osteoporosis and low bone mass (osteopenia) which will increase the risk of falls and fractures (Weaver et al., 2016). The most modifiable way to maintain bone strength is through diet and physical activity. For instance, optimum meal intake with calcium and vitamin D and involvement in exercise with weight-bearing (i.e. running, walking) will strengthen the bone (Beck et al., 2017).

Bone strength is also important in maintaining a good body posture. While a good body posture can be defined as an ability of the body to hold itself in a way that may put the least strain on the joints, ligaments and muscles in daily activities (Conyers & Webstrer, 2012). It is important to have a good body posture because it will reduce the probability of getting posture problems (i.e. back pain, forward head) and helps in improving our spine health status. A good posture can be sustained through a few forms of strength exercise that focus on abs, abdominal, low back muscle and pelvis (i.e. forearm plank, overhead arm raise, shoulder pull back, hip flexor stretch, thoracic foam roll and head retraction). Some studies have shown that as age increases, people will

start to lose their muscular strength and power which will lead to the loss of mobility and balance (Baggen et al., 2019; Daly et al., 2019; Marques et al., 2017).

In the elderly population, previous study showed that significant issues with gait function (Melzer et al., 2004). Therefore, elderly people have a higher probability of getting serious injuries because of falls and might also have a fear of falling that affects their cognitive performance (Marques et al., 2017; Solloway et al., 2016). In contrast, young individuals rarely have bone and stability problems due to greater bone mass density and functional performance than the older population (Chen et al., 2015). They always have a good bone health status, whereby it reduces the risk of bone fracture while doing physical activities (Baggen et al., 2019). Teenagers have better body stability than the elders (Chen et al., 2015).

Aerobic exercise can be defined as a subcategory of physical exercise that requires the use of oxygen from aerobic metabolism to meet the adequate energy demands during exercise (Schootemeijer et al., 2020). Aerobic exercise is significantly carried out for extended periods by repeating sequences of low to moderate-intensity exercise. It relies primarily on the large muscles of the body as a continuous movement in a rhythmic way. The muscles that are stimulated, as well as the duration and intensity of the activity, can all be used to determine the type of aerobic exercise. Generally, the benefit of performing aerobic exercise is the increase of heart rate, calories intake, stroke volume and improving individual physical fitness. A few types of exercises have been proposed to enhance bone mass density and reduce the risk of falls such as resistance, balance and strength training exercises. Previous studies related to aerobic exercise and bone stability among patients have shown the most significant difference in bone mass findings. In brief, the patients who are involved in the research are having health

problems related to the low bone mass condition (Daly et al., 2019; Yuan et al., 2016). The most common bone-related diseases were osteoporosis, osteoarthritis and low back pain which most likely affects the patients' postural balance to perform any physical activity (Al-Khlaifat et al., 2016; Braghin et al., 2018; Otero et al., 2017; Shamsi et al., 2017; Ye et al., 2020; Yuan et al., 2016). Resistance exercises have also been suggested to improve the muscular strength in enhancing proprioception and dynamic balance of elderly people (Baggen et al., 2019; Carrasco-Poyatos et al., 2019; Daly et al., 2019; Kim et al., 2020; Seo et al., 2012; Solloway et al., 2016).

To date, based on literature search, the studies on the effects of aerobic exercise on bone strength and posture are not properly reviewed. Thus, this review aims to investigate the recommended type of aerobic exercise for the high-risk populations to improve bone strength and postural stability. The advantage of this review is that it could provide a guideline and exercise prescription for high-risk population such as patients, the elderly and active individuals. This review could also be used as a standard for training instructions for training programmes and also useful for rehabilitation processes in monitoring the recovery improvement (Solloway et al., 2016).

1.2 Problem Statements

Elderly individuals are prone to have osteoporosis and a high risk of falling due to aging and low physical activity level. There is a lack of evidence to acknowledge the relations of aerobic exercise with the risk of falling and osteoporosis. Eventhough the effects of aerobic exercise on bone strength and posture are well established, no reviews were done specifically for a different population. Patients and healthy individuals were found to have bad posture because of poor dieting habits and poor ergonomic posture during work and daily activities. Basic data from previous studies are needed regarding the most suitable and recommended exercise that can be done and promoting an exercise guideline to the different populations.

1.3 Research Questions

1. What are the aerobic exercises prescription that can be recommended to strengthen the bones?
2. What are the aerobic exercises prescription that can be recommended to improve postural stability?
3. What are the best aerobic exercises prescription that could be suggested for healthy individuals, the elderly and patients to strengthen the bone and improve postural stability?

1.4 Study Objectives

1.4.1 General Objective

To review the aerobic exercise prescriptions for bone strengthening and improving postural stability

1.4.2 Specific Objectives

To review the aerobic exercise prescriptions that can be recommended for bone strengthening.

To review the aerobic exercise prescriptions that can be recommended for improving postural stability.

To review the best aerobic exercise prescriptions that could be suggested for healthy individuals, the elderly population, and patients for bone strengthening and improving postural stability.

1.5 Significance of the Study

This research is a review about how aerobic exercises may promote a good health standard, by measuring bone strength and postural stability as outcome measures. The significance of this research would notify the best type of exercises that can be recommended based on the published papers for healthy individuals, the elderly population, and patients. In addition, this study could be used as a guideline for exercise prescription for different populations. The information can be used to educate the targeted population regarding the information on frequency, intensity, duration and type of aerobic exercise and its effects on bone health status and body posture.

Chapter 2

Literature Review

2.1 Bone and Its function

Bone can be interpreted as a specific form of connective tissue that is physiologically mineralised to create the skeletal system in our body (Gasser & Kneissel, 2017; Safadi et al., 2009). While bones as individual organs are a combination of bone, cartilage, fat, connective tissue, hematopoietic tissue, nerves and vessels (Tzelepi et al., 2009). On the cell level, it can be divided into three types of bone cells: osteoblasts, osteoclasts and osteocytes. The primary cells (osteoblasts) are responsible for bone development (osteogenesis) and mineralisation while bone resorption is mainly the responsibility of osteoclasts (Safadi et al., 2009). Osteocytes were developed to withstand mechanical forces towards the bone surface. Mesenchymal stem cells are derived from osteoblasts and osteocytes, whereas hematopoietic stem cells are derived from osteoclasts and are linked to monocyte/macrophages. Thus, the hardening of the bone matrix, will trap osteoblasts which then become osteocytes, forming the bone.

Studies have shown that two types of bone tissue are classified based on collagen fiber arrangement: woven bone and lamellar bone (Safadi et al., 2009). Woven bone is designed with a high number of osteoblasts and osteoprogenitor cells and is commonly found in the growing fetus. Even though it is an immature type of bone, woven bone has a rapid formation and reabsorption process. Because of its disorganised structural organization form, woven bone elastically resists the forces that come from all directions. Lamellar bone has a well-oriented collagen fibre organisation and is often known as mature adult bone which is more rigid and stronger than woven bone. This type of bone has a slower process of mineralisation and a longer period for deposition of

the organic matrix. Histologically, there are two types of bone which are compact bone and trabecular bone. In short, compact bone refers to mature bone that is found in between lamellae or also called osteocytes while trabecular bone or also called cancellous bone is a spongy spicule of bone that is located in between marrow space (Tzelepi et al., 2009).

Based on previous research from Safadi et al. (2009), there are eight generals structures of bone: cortical (compact) bone, epiphysis, physis (epiphyseal plate), metaphysis, diaphysis (shaft), periosteum and endosteum. Compact bone is a component that is surrounded by a marrow cavity and acts as the outer shell of the bone regardless of its actual positions between the periosteum and endosteum. The epiphysis is a component that mostly consists of spongy bone which can be found in between the physis and articular cartilage. While epiphyseal plate (physis) is only found in growing children; and if this component gets fractured, it is possible to result in angular deformity (Safadi et al., 2009). Additionally, there is a component called diaphysis which is located on the middle portion of a tubular bone. There is also a space between the diaphysis and physis/ epiphysis which is called metaphysis. Bone marrow is known as the medullary cavity which is filled with fat, hematopoietic marrow and trabecular bone. The portion of bone marrow that can be found in younger people is more dominant than in elderly adults. Moreover, a layer of membrane on the surface of the bone is known as the periosteum, consists of blood vessels, fibroblasts and nerves that contribute to bone elongation. In closing, the last component of bone structure is the endosteum which is composed of a resting layer of marrow (Safadi et al., 2009).

The bone classification can be divided into two ways which is the manner of embryological development and through its shape and size (Tzelepi et al., 2009). According to Safadi et al. (2009), the feature of bone can be identified grossly into five types which are long bones (i.e., femur, fibular, humerus, radius, tibia and ulnar), short bones (i.e., metacarpal, and metatarsal), flat bones (i.e., scapula, sternum, and skull bone), irregularly shaped bones (i.e., ethmoid and vertebra) and sesamoid bones which are embedded bones in tendons (i.e., patella and pisiform). The main function of the bones is to provide mechanical support for our body and protection for the vital organs. For instance, there is a cranial cavity where the brain resides is created by skull bones and the presence of pleura and the thoracic vertebrae in thoracic cage is essential for the defense of the heart and lungs. Trabecular bone is an active bone component that has the ability to resist greater mechanical compression which is good for bone strength and bone mass maintenance. Hence, there is a low risk of bone fracture when it is exposed to high force components during physical activities (Safadi et al., 2009).

Thus, there are three climax phenomena in the normal bone remodeling: (1) osteoclasts inhibit the bone formation via expressing semaphorin4D (Sema4D), (2) osteoblasts impede the bone resorption by expressing Sema3A, and (3) osteocytes generate factor that exerts anabolic bone action before dying and osteocytes will be removed from remodeling site. This process occurs due to coordinated actions of osteoclasts, osteoblasts, osteocytes, and bone lining cells which together form the temporary anatomical structure called basic multicellular unit (BMU) for new bone development (Florencio-Silva et al., 2015).

2.2 Postural stability and its importance

Based on Chaudhry et al. (2004), postural stability can be defined as a response towards the dynamic postural movement, whether it has been intentionally applied or volitional disturbances. In contrast, postural control is typically called "postural steadiness" under static conditions. Postural control is a term used to denote how sensory information from other systems is regulated by our central nervous system (CNS) in order to generate sufficient motor output to maintain a balanced, upright posture. The major sensory systems that will be involved in postural control and balance are the visual, vestibular, and somatosensory systems (Alcock et al., 2018). When a person participates in various static and dynamic activities, such as sitting, standing, kneeling, quadrupling, crawling, walking, and running, with the ability to contract the necessary muscles needed for a stable midline posture, as well as the ability to make minor adjustments in response to position changes and its activities, without the use of compensatory motions.

Posturography is a type of computerised test that has been used to identify postural control either in static or dynamic position for upright stance (Chaudhry et al., 2004). In brief, the key clinical test that has been used in dynamic posturography is Sensory Organisation Test (SOT) which brings an outcome called equilibrium score (ES). ES is used to examine the overall function of the visual, proprioceptive, and vestibular systems for the maintenance of standing posture. However, the function of ES meets the main functional objective of postural control which is for the orientation and equilibrium of our body posture. The body's alignment and tone are controlled by postural orientation in terms of gravity, support surface, visual setting, and internal references. During both self-initiated and externally activated stimuli, the synchronisation of sensorimotor techniques to maintain the center of mass of the body constitutes postural

balance (Chaudhry et al., 2004). These show the importance of visual, proprioceptive and vestibular sensory systems are towards postural balance.

Therefore, the visual system acts as the first sensory information receiver improving postural stability. There are two practical types of eye movements: gaze stabilisation and gaze shifting (Alcock et al., 2018). Gaze stabilisation is a technique that involves the vestibulo-ocular and optokinetic systems to keep the eye stable while the head moves or shifts. When a visual target shifts or moves, individuals who maintain the vision of the visual target fixed on the eye are seen to be gaze shifting. There are three functions of gaze shifting in focusing the visual image on the fovea of the eyes. Smooth pursuit makes use of the eyes to monitor a visual target's movement. Alteration of vergence helps to modify the angle of eyes to get a clear distance to near images. At the same time, saccadic eye movements will help individuals to bring the visual target into their view limits. Saccades are quick and jerky movement of eyes in two or more phases of fixing view into the same direction. Thus, the visual system is necessary to understand the postural balance in clinical settings (Bloem et al., 2003).

Additionally, the vestibular system accommodates the trunk vertically by using sensory orientation and weighting appropriate sensory signals in various sensory conditions. For example, the patient was asked to stand on an inclined surface or on foam, or with their eyes closed. The postural responses (patient stands or walks a beam) or stabilisation of the patient’s head (leans or is tilted) during postural movement will be able to control the body's center of mass (COM) for both static and dynamic positions (Hain, 2011; Ivanenko and Gurfinkel, 2018; Yang et al., 2019). The somatosensory system requires the involvement of sensory neurons that are very sensitive towards touch, pressure, pain, temperature, position, movement and vibration which comes from

the internal or external of our body. However, mechanoreceptors are the specific sensory neurons associated with the postural control system. It provides information about muscle spindles such as muscle's length and its velocity of contraction which are helpful to alter the individual's movement in the postural control system (Kröger, 2018; Shaffer and Harrison, 2007).

According to Mahant and Stacy (2001), when an individual starts to age, the tendency to have movement limitations is one of the most prominent issues in the elderly population. There are two types of movement disorders which are hypokinetic (i.e., Parkinson's disease) and hyperkinetic (i.e., essential tremor). A normal aging process causes muscle atrophy which leads to the declining of power and strength of the individual's lower extremities. In addition, they will also lose their balance and coordination in mobility which causes the restriction of mechanical movement (Marques et al., 2011; Otero et al., 2017).

Postural stability is an important component in determining the effectiveness of interventions to improve balance. The premier importance of having good postural stability is to reduce the risk of falling and fall-related injuries. According to (Ye et al., 2020), it is reported that muscle weakness and pain are associated with decreased postural function, as pain inhibits muscle activation and range of motion. The decline of postural stability is very significant with the elderly population because they have balance and gait impairment that contribute to falls (Melzer et al., 2004). There are many forms of balance tests to determine the ability of body posture to maintain control. Therefore, a few types of exercise have been introduced to enhance body function abilities, especially postural stability, muscular strength and flexibility. It is also helping in reducing the pain scale that causes bone-related disease.

2.3 Exercise prescriptions to improve bone strength and stability.

In order to achieve individual wellness and physical fitness objectives, an exercise training programme needs to be planned ideally. The concepts of exercise prescription are intended to help exercise and health/fitness practitioners in creating a personalised exercise guideline. The guideline for an exercise programme is commonly recommended for healthy adults; any modifications are allowed as long it meets the individual's goals (American College of Sports Medicine, 2010). In choosing the exercise mode in an exercise programme, there are a few aspects that should be considered such an individual's objective, physical capability, health condition and availability of the equipment. For the exercise prescription, it is not necessary to combine all the physical fitness components into one programme if the aspects of the exercise modalities as above were met. Based on a combination of the frequency and intensity of exercise, recommendations can be made based on Table 1 (American College of Sports Medicine, 2010).

Table 1. General exercise recommendations for healthy adults

WEEKLY FREQUENCY (Day per week are denoted to an exercise programme)	**TYPES OF EXERCISE**
At least 5 days per week	Moderate intensity (40% to <60% VO_2R) aerobic (cardiovascular endurance) activities, weight-bearing exercise, flexibility exercise
At least 3 days per week	Vigorous-intensity (≥60% VO_2R) aerobic activities, weight-bearing exercise, flexibility exercise

3–5 days per week	A combination of moderate- and vigorous-intensity aerobic activities, weight-bearing exercise, flexibility exercise
2–3 days per week	Muscular strength and endurance, resistance exercise, calisthenics, balance and agility exercise

2.3.1 Exercise prescription for individuals with low bone mass and high risk of falling.

According to Beck et al. (2017), the rate of morbidity and mortality in people with health problems is associated with osteoporotic fractures. While current recommended guidelines are common and not specialised for the prevention and management of osteoporosis. In addition, generalised exercise guidelines may not develop the individual's bone health, functional ability and reduce the risk of fracture. Since aerobic exercise is notable as cardio-respiratory exercise or in brief it is known as fat-burning exercise, it should be performed as minimum as 30 minutes. Thus, to maintain prolonged physical activity, exercise must be done at a low to moderate intensity by increasing maximum heart rate or maximum rate of oxygen uptake which are good for oxidation of fat into an energy form.

Aerobic exercise is separated into two types of impact with different benefits and risks towards a sufficient bone stimulus. Conventionally, high-impact exercise often involves bounding and jerky movements, which is good for cardiovascular fitness and enhancing bone density (Said et al., 2017). As for the low-impact exercises, they can be performed in a fluid-like motion and produce more gentle forces towards our joints, therefore the least risk of injury involved along with the development of body flexibility

and stability (Said et al., 2017). However, yoga cannot be considered part of aerobic exercise because it is unable to increase the ability of cardiorespiratory endurance (Akhtar et al., 2018). Thus, Table 2 provides an exercise prescription for individuals with osteoporotic fractures which is applicable for bone strengthening and improving postural stability (Beck et al., 2017).

Table 2: Exercise prescription for the prevention and management of osteoporosis according to level of risk for fragility fracture

Exercise mode	Exercise components	Low risk individuals (prevention of OP)	Moderate risk individuals (prevention of OP)	High risk individuals (management of OP and prevention of falls)
Impact loading	Vertical and multidirectional jumping, bounding, hopping, skipping rope, drop jumps and bench stepping. Progress body weight (BW) intensity by increasing heights for activities such as bounding and drop jumping, adding weighted vests and changing directions. Impact loading can be interspersed between balance and resistance training exercises. using weighted vests, changing direct of movement	Intensity: High impact activities (>4 body weight), as tolerable Frequency: 4–7 days per week Sets/Repetitions: 50 jumps per session (3–5 sets of 10–20 repetitions with 1–2 min rest between sets)	Intensity: Moderate-to-high impact activities (>2 body weight), as tolerable Frequency: 4–7 days per week Sets/Repetitions: 50 jumps per session (3–5 sets of 10–20 repetitions with 1–2 min rest between sets)	Intensity: Moderate impact activities (2–3 body weight), within the limits of pain, increasing as tolerated. Frail individuals will require a period of PRT to develop adequate strength to perform some impact activities. Frequency: 4–7 days per week Sets/Repetitions: Aim to work up to 50 repetitions over time (5 sets of 10 repetitions with 1–2 min rest between sets) Frail individuals should be supervised and exercise within

				reach of a railing or other stable support.
Progressive resistance training (PRT)	8 exercises per session targeting major muscle groups attached to the hip and spine including (on a rotating system): weighted lunges, hip abduction/adduction, knee extension/flexion, plantar-/dorsi-flexion, back extension, reverse chest fly's, and abdominal exercises, or a smaller number of compound movements such as squats and deadlifts.	Intensity: High to very high (80–85% 1RM; ≥16 on Borg 6–20-point RPE scale or 'Very hard') Frequency: 2 days per week Sets/Repetitions: 2–3 sets of 8 repetitions. Consider including high velocity (rapid) PRT exercises to enhance muscle power and function Avoid deep forward spine flexion. Training in technique and supervision is essential.	Intensity: High to very high (80–85% 1RM; ≥16 on Borg 6–20-point RPE scale or 'Very hard') Frequency: 2 days per week Sets/Repetitions: 2–3 sets of 8 repetitions. Consider including high velocity (rapid) PRT exercises to enhance muscle power and function Avoid deep forward spine flexion. Training in technique and supervision is essential.	Intensity: High to very high (80–85% 1RM; ≥16 on Borg 6–20-point RPE scale or 'Very hard') Frequency: 2 days per week Sets/Repetitions: 2–3 sets of 8 repetitions. Consider including high velocity (rapid) PRT exercises to enhance muscle power and function Avoid deep forward spine flexion. Training in technique and supervision is essential.

Balance training	Standing and moving exercises with gradual reduction in base of support to standing on one foot, perturbing the center of mass with leaning and reaching then regaining balance with minimal use of support from the upper extremities. E.g., Tai Chi, single leg stance, tandem stance, tandem walk, backwards, sideways and crossover walks, circle and pivot turn, figure of eight walks, stepping over and avoiding obstacles, walking on uneven surface. Progress by altering surface (foam mats) and reducing base of support, longer	Intensity: Challenging Frequency: Incorporate balance activities where possible into strength and impact elements of the exercise programme. Tasks performed with eyes closed should be done in proximity to a railing or other secure support.	Intensity: Challenging Frequency: 4 sessions per week Sets/Repetitions: 30 min of a variety of balance exercises per session; at least 10 sec per balance exercise and at least 10 steps forward and back for mobility exercises, increasing as tolerated to longer durations. Could be accomplished within other exercise bouts during the course of a week. Tasks performed with eyes closed should be done in proximity to a railing or other secure support.	Intensity: Challenging Frequency: 4 sessions per week Sets/Repetitions: 30 min of a variety of balance exercises per session; at least 10 sec per balance exercise and at least 10 steps forward and back for mobility exercises, increasing as tolerated to longer durations. Could be accomplished within other exercise bouts during the course of a week. Frail individuals should be supervised to prevent falls during balance training and exercise within reach of a railing or other secure support.

	or faster steps, heel and toe walks, raised arms walk, withdrawing vision during balance tasks, and dual tasking (e.g., cognitive task such as counting backwards or naming animals, combined with balance activities).			

Chapter 3

Materials and Methods

3.1. Data sources

Related studies were searched electronically using the following databases: PubMed, Scopus, Springer Link and Science Direct. Briefly, the selected studies were hand-searched using the same selection criteria as described below. In addition, cross-referencing on the related studies was performed to obtain additional information. Peer-reviewed articles in the English language from 2011 until 2021 were used. No attempts were made to contact the authors for additional information.

3.2. Study selection

The search was conducted according to the Preferred Reporting Items for Scoping Reviews and Meta-Analyses (PRISMA) flow guidelines (Liberati et al., 2009). The following keywords were used during the search: #aerobic exercise and (#bone and #stability). Studies were screened for performing aerobic exercises as intervention, treatment, or physical activity and bone stability or postural balance as outcome measures. Controlled trials and laboratory studies on humans only were included in this review. The exercise interventions comprised of brisk walking, Tai Chi, Thai boxing dance, soccer, Qigong (Ba Duan Jin) exercise and a various component of exercises such as plyometric, stabilisation, strengthening and proprioception. Outcome measures of bone and stability are described: (1) risk of falls (2) bone strength, (3) body balance, or (4) postural stability.

PRISMA flow has been produced based on pre-determined stages which are identification, screening, and eligibility and inclusion. The initial search from the databases identified 669 potential articles. After removing duplicates, 668 articles were assessed based on titles and abstracts against the selection criteria. A total of 612 articles were excluded

because they did not investigate aerobic exercise, bone strength, body stability, or exercise prescriptions. Instead, the reasons behind the huge number of full-text articles rejection were because there were 411 articles were not the type of exercises and structures in the inclusion criteria, about 156 articles were totally unrelated study outcomes, while 43 articles were conferences and evaluation papers. After a detailed analysis of full-text articles, only 15 were included. The process of study selection paper as shown in Figure 1.

3.3. Data extraction

The titles and abstracts of retrieved articles were reviewed using the criteria specified to determine whether full texts were required for further analysis. Each full-text manuscript was evaluated systematically according to the study: (1) objective/s, (2) characteristics of the study (study design, participants, age and sample size), (3) intervention content (intervention types, length of intervention, or mode of exercise tested (4) targeted outcome/s, and (5) main findings. The outcomes extracted from those studies were not combined, reanalysed, or changed due to the nature of this systematic review.

3.4 Study Flowchart

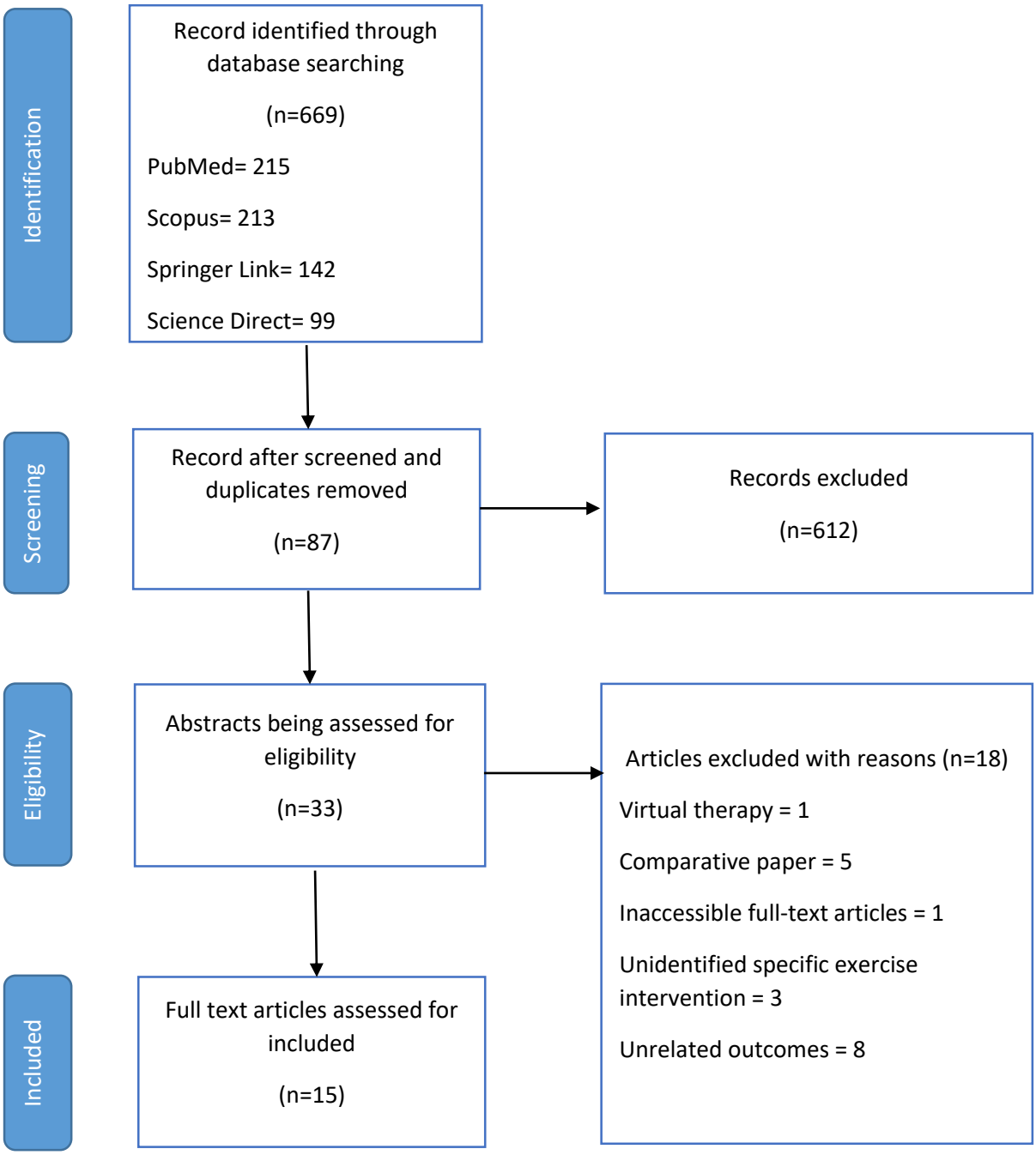

Figure 1 PRISMA flow for study selection

Chapter 4

Results

4.1 Search results

The initial search from the databases identified 669 potential articles. After removing duplicates, 87 articles were assessed based on titles and main keywords against the selection criteria. A total of 612 articles were excluded because they did not investigate the effect of aerobic exercise on bone strength and postural stability. After a detailed analysis of the 33 abstracts and full-text articles, only 15 were included in this scoping review. The excluded articles were comparative papers, inaccessible full-text articles, unidentified specific exercise intervention, unrelated outcomes and virtual therapy. Fig. 1 describes the PRISMA flow diagram for the study selection.

From the 15 studies reviewed, only one study focused on bone strength while the remaining 11 were about postural stability. Another three studies investigated the effect of aerobic exercise on both bone strength and postural stability. The scope of study from those retrieved articles was primarily on the effects of aerobic exercise prescription on bone strength and postural stability.

Secondarily, few studies investigated the effect of aerobic exercise prescription as an intervention on various groups of subjects whether they are from the active individuals, elderly population or the patients' groups. These studies include bone health status, risk of falling, bone strength and balance performance.

4.2 Effects of aerobic exercise prescription on bone strength

Table 3 summarises the effects of aerobic exercise prescription on bone strength. One study was conducted on soccer players focusing on the effects of training on their bone strength. A combination of techniques used in soccer such as dribbling, shooting, passing, and precision, trapping and receiving a ball provides a great impact on the stimulation of bone mineralisation which results in increased bone mass and prevention from bone fractures.

4.3 Effects of aerobic exercise prescription on postural stability

Table 3 summarises the effect of aerobic exercise prescription on postural stability. Three studies reported that Tai Chi training may improve leg balance and power. The study was applied to patients, elderly and active individuals and it shows that Tai Chi is a good and suitable form of exercise to be used on any group of people. Two of these studies investigated aquatic exercise which it was beneficial to reduce the risk of falling especially in the fibromyalgia patients and the elderly group. One study found that a combat sport was also affecting postural stability by reducing the risk of falling and improved balance in the elderly group. One study conducted on the university students reported that stabilisation exercise was able to reduce the postural back pain while another study on strengthening exercise involving elderly patients reported a decrease in the risk of fall, besides enhancing the balance and proprioception elements. Another study involves stabilisation exercise in scoliosis patients, which was able to showing enhancement of postural balance. There are two studies that involved walking exercise; one study reported that Nordic walking in elderly with osteopenia or osteoporosis was able to increase the cardiovascular fitness despite improving one's balance. Another one study investigated the combination of walking and strengthening exercises helps in lowering the rate of the seriousness of the fall-related injury.

4.4 Effects of aerobic exercise prescription on bone strength and postural stability

Three studies reported changes in both bone strength and postural stability. One study on an elderly group performing plyometric training showed improved functional performance, while another study which involved brisk walking exercise has been shown to prevent the deterioration of postural stability. One study was conducted on patients' group which employed the Qigong training and their results indicated that besides reducing the risk of falling, the participants also gained bone mass density and improved balance performance.

Table 3: Effects of aerobic exercise prescription on bone strength and postural stability for healthy individuals

No.	Authors and year	Study target/ target population	Frequency/ duration/ Intensity	Intervention/ exercise program	Outcome measures	Main finding
1	Koury et al., 2018. Bio impedance parameters in adolescent athletes in relation to bone maturity and biochemical zinc indices	Randomised - control study, n= 40, of adolescent male soccer athletes Subject does not take any dietary supplements/ does not change their diet during study	-	Each subject practised soccer at least 20 hours per week and being active playing soccer for 5 years. No specific intervention programme provided.	Skeletal maturity, Anthropometric; total body mass, height, BMI BIVA; provide information on hydration status, body cell mass and cell integrity Zn biochemical indices; plasma zinc, erythrocyte zinc Bioelectrical data; phase angle, resistance and reactance	Demonstrate the bone age and erythrocyte zinc were significantly associated with phase angle (PA) in adolescent soccer athletes Bioelectrical impedance vector analysis (BIVA) is influenced by skeletal maturity status of the adolescent athletes.

2	Sciamanna et al., 2018. Working to Increase Stability through Exercise (WISE): Study protocol for a pragmatic randomised controlled trial of a coached exercise program to reduce serious fall-related injuries	A stratified randomisation study on 1130 subjects with age of ≥65 years and high risk of fragility fracture or osteoporosis. 36-months intervention: strength, balance and aerobic exercises.	30-minute include 2 sets of 12 repetitions of six strength exercises, 20-minute per session of balance exercise and 4500 steps per day of walking exercise.	Each subject performed strength training about twice a week (e.g., resistance bands exercises), balance exercise for 3 times per week (e.g., single-leg stance, stepping and side bends) and aerobic exercises for 5 times per week (e.g., walking step goal). Senior Fitness Test (SFT) which use chair stands and arm curls exercises to enhance	Fragility fracture Serious fall-related injury Emergency department visits Inpatient hospitalisation Bone mass Muscle mass Strength testing Number of falls Loneliness Falls Efficacy scale international Self-reported health Depression, Pain, Fatigue, Anxiety, Physical function, Sleep	Differentiate the rate of seriousness of fall-related injury (SFRI) between conditions; 13% of control subjects versus 7% of intervention subjects experience the SFRI.

				subjects' physical function which is also equivalent to a leg press, the progressive strength exercise.	disturbances, social roles and Activities Physical activity Cognition Blood pressure and heart rate Covariates Caregiver status Height and weight Demographics Past medical history Osteoporosis	

3	Zou et al., 2019. Superior effects of modified Chen-style Tai Chi versus 24-style Tai Chi on cognitive function, fitness, and balance performance in adults over 55	Randomised control study, n= 80 eligible adults aged over 55 12-weeks intervention: Modified Chen-style Tai Chi (MTC), 24-style Tai Chi (TC-24)	40-70 minute per session 3 times per week Outcome assessment were performed thrice time periods; baseline, week 6 and week 12	Each subject performed the modified or 24-style Tai Chi exercises. Assessment involved: 1) Montreal Cognitive Assessment (MoCA) 2) One-leg standing test (OLST) 3) Timed Up-and-Go test (TUGT) 4) Chair Stand test (CST) 5) Six-meter Walk test (6MWT)	Overall cognitive function Static balance Dynamic balance Leg power Aerobic exercise capacity	Any form of Tai Chi is beneficially improved the cognitive function, balance and fitness but MTC seems more effective to enhance these health-related parameters in elderly population.

Table 4: Effects of aerobic exercise prescription on bone strength and postural stability for elderly population

No.	Authors and year	Study target/ target population	Frequency/ duration/ Intensity	Intervention/ exercise program	Outcome measures	Main finding
1	Ossowski et al., 2016. Effects of short-term Nordic walking training on sarcopenia - related parameters in women with low bone mass: A preliminary study	Randomised control study, n= 45 women, aged 63-79 years, with osteopenia or osteoporosis 12-weeks intervention	60-minute per session 3 times per week	Each subject performed the isometric muscle strength; measured using Biodex System 4 Pro™ dynamometers or SAEHAN Digital Hand Dynamometer Assessment involved: 1) Timed up-and-go test 2) 6-minute Walk test	Handgrip muscle strength Functional performance Functional mobility Body composition Isometric muscle strength (knee extensor and flexor)	Nordic walking training induces positive changes in knee muscle strength and functional performance in women with low bone mass

2	Martinez-Carbonell Guillamon et al., 2019. Does aquatic exercise improve commonly reported predisposing risk factors to falls within the elderly? A systematic review	Randomised control study, on healthy adults aged between 60 and 80 years old 2-24 weeks intervention; most intervention 8 – 12 weeks	40-90 minutes per session 2-3 times per week Variation in: Water temperature: 28 – 32^{o}C, Water depth: waist-chest, Intensity via RPE scale: moderate to high	Each subject performed the aquatic exercise using these resistance materials: (1) power leg and power hand DESCENTE Co., Ltd., Japan (2) Aqua Flex paddles by MIZUNO Corporation, Osaka, Japan (3) by opening the webbing of the Aqua Mitt gloves	Physical function and/or physical performance Prescription of exercise; intensity, volume and frequency Type of aquatic exercise; water-based training, water/aquatic exercise or hydrotherapy	There was limited and low-quality evidence to prove the use of aquatic exercise may reduce the risk of falling. Aquatic exercise training was unreliable due to the lack of control of the training load during exercise environment. In term of variables, resistance materials present better results in gait speed compare to strength, flexibility and mobility training.

3	Lin et al., 2019. Simplified Tai Chi 6-Form Apparatus for Balance in Elderly People with Alzheimer Disease	Case-controlled study, n= 26 elderly people with mild-to-moderate Alzheimer disease (AD) 8-weeks intervention: TC group training, Control group	45-minutes per session, 2 times per week Evaluated 3 times; at beginning, week 4 and week 8	Each subject performed the simplified Tai Chi 6-form apparatus (STC6FA). Assessment involved: 1) Balance testing 2) Rhythmic forward-backward shift test	Balance function (static and dynamic), Rhythmic forward-backward shift, Mental state and dementia scores (MMS), Behavioural pathology in Alzheimer's disease rating scale (BEHAVE-AD), Depression score in dementia (CSDD)	The balance control of both groups improved significantly. STC6FA helps to reduce risk of backward falls and other fall-related injuries in AD and elderly people. A rhythmic forward-backward shift test seems improve in the training group.

4	Penn et al., 2019. Effects of individualised Tai-Chi on balance and lower-limb strength in older adults	Single-blind study design, n= 50 older adults aged 65 and above 8-weeks intervention: Individualize Tai Chi (iTC), Traditional Tai Chi (tTC), Control group	30-minute per session, 3 class per week	Each subject practised a complete Yang-Style Tai Chi exercise 2-3 times per session. Assessment involved: 1) Functional balance test 2) Berg Balance Scale (BBS) 3) Timed up-and-go test (TUGT) 4) Functional reach test 5) Measurement of lower extremity muscle strength	Lower extremity muscle strength Maximal distance of the arm reaches forward Balance control and proprioception Enhance the postural adaptation Reduces the risk of falling in older adults	There was minimal evidence that shows the improvement in leg balance from Tai Chi exercise depends on the graded intensity and the complexity of the practices.

5	Areeudomwong et al., 2019. Balance and functional fitness benefits of a Thai boxing dance program among community-dwelling older adults at risk of falling: A randomised controlled study	Randomised control study, n= 78 subjects 4-months intervention: TBD program group, Control group	30-minute of TBD per session Once a week	Each subject performed Thai Boxing dance or/ and given with the fall prevention booklet Prior to TBD: - Warm-up on stationary bicycle (5min) - Upper body stretching (5min)	Static and dynamic balance performance, Functional fitness Lower limb muscle strength Body flexibility and agility	TBD as an intervention for improving balance and functional fitness of community-dwelling seniors at risk of falling Participants showed greater improvements in static balance with eyes open, dynamic balance and all functional fitness.

6	Vetrovsky et al., 2018. The Efficacy and Safety of Lower-Limb Plyometric Training in Older Adults: A Systematic Review	Randomised control study n= 289 subjects (176 females and 113 males) with ≥60 years 4-weeks intervention: 15 groups, n= 8–36 per group	2-3 times per week for 12 months	Each subject performs plyometric training which may including resistance, balance, agility and aerobic exercises. Consist of 30s sit-to-stand test, figure-of-8 running, timed up-and-go test, 6m fast walk, shuttle run test, stair climb and squat jump to evaluate the effectiveness of plyometric exercise.	Muscular strength, Bone health, Body composition, Postural stability, Physical performance Jump performance	Plyometric training is a feasible and safe training option with potential for improving various performance, functional, and health-related outcomes in older persons

Table 5: Effects of aerobic exercise prescription on bone strength and postural stability for patients

No.	Authors and year	Study target/ target population	Frequency/ duration/ intensity	Intervention/ exercise program	Outcome measures	Main finding
1	Rivas Neira et al., 2017. Effectiveness of Aquatic Therapy vs. Land-based Therapy for Balance and Pain in Women with Fibromyalgia: a study protocol for a randomised controlled trial	Single-blind and randomised control study, n= 40 women with fibromyalgia 3-months intervention: Aquatic Therapy, Land-based Therapy Post-treatment: 6 weeks	60 minute per sessions 3 times a week	Each subject performed warm-up, proprioceptive exercises, stretching and relaxation. Physical assessment done at baseline, immediately after the end of treatment and at 6-weeks follow-up	Balance; static and dynamic Pain; the intensity and threshold Functional balance, Quality of life, Quality of sleep, Fatigue, Self-confidence in balance and physical ability.	Improvement in pain intensity, physical function and quality of life. Aquatic environment of exercise may reduce impact on joints, improves microcirculation, facilitates relaxation, and improves muscle tone and decrease number of contractures

2	Gezginaslan et al., 2018. Effects of isokinetic muscle strengthening on balance, proprioception, and physical function in bilateral knee osteoarthritis patients with moderate fall risk	39 subjects, with mean age 61.7 ± 8.6 years range and, Conditions: Grade 2 or 3 knee osteoarthritis (OA) 6-weeks intervention	3 times per week 25 second rest between angular velocity 5-minute rest interval between left and right limb	Each subject performed the isokinetic muscle strengthening exercises Assessment involved: 1) Berg Balance Scale (BBS), 2) Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) subscale scores, 3) Visual Analogue Scale (VAS) scores	Quadriceps and hamstring muscle strength Muscle range of motion Proprioception Balance control Physical function Level of pain Joint stiffness	Isokinetic exercise had significant effects on balance, proprioception and physical function even in patients who has been in Grade 2 or 3 OA with moderate risk of fall Improve the quality of life and contribute to the decreased risk of fall

3	Çelenay and Kaya, 2017. An 8-week thoracic spine stabilisation exercise program improves postural back pain, spine alignment, postural sway, and core endurance in university students: a randomised controlled study	Randomised control study, n= 33 university students 8-weeks intervention: Exercise group Control group With 3 progression phases: -Static -Dynamic -Functional	25 minute of stabilisation exercises 3 days per week	Each subject performed the warm-up, stabilisation exercises, cool-down and stretching exercises. Assessments involved: 1) Spinal Mouse, Biodex Balance System, 2) McGill's trunk muscle endurance test 3) Visual Analogue Scale (VAS)	Postural pain, Spinal alignment, postural sway, and core endurance Dynamic stability index (eyes closed) Core endurance scores	(i) postural back pain decreased in the exercise group, (ii) decreased the thoracic and lumbar curvature in the standing position, whereas no difference was observed for the controls, (iii) the training changed the overall postural sway only in the eyes closed position,

						(iv) the core endurance improved in the training group
4	Gür et al., 2016. The effectiveness of core stabilisation exercise in adolescent idiopathic scoliosis: A randomised controlled trial.	Randomised control study, n= 25 subjects with idiopathic scoliosis 10-weeks intervention: Stabilisation group, Control group	60 minutes per session, 2 times per week	Each subject performed the core stabilisation exercises. Assessments involved: 1) Posterior Trunk Symmetry Index, 2) Trunk Appearance Perception Scale, 3) Scoliosis Research Society-22 questionnaire, 4) Radiograph and Adam's test	Postural balance, Cob's angle, Apical vertebral rotation, Trunk asymmetry, Cosmetic trunk deformity Quality of life	Core stabilisation exercise effective in the correction of vertebral rotation and reduction of pain in adolescent idiopathic scoliosis

5	Gába et al., 2016. The effect of brisk walking on postural stability, bone mineral density, body weight and composition in women over 50 years with a sedentary occupation: A randomised controlled trial	Randomised control study, n= 58 subjects, women with age range ≥50 years 10-weeks intervention	30-35 minute per session, 5 times per week	Each subject performed the walking intervention whether it is a self-regulated brisk walking or to/ from work brisk walking.	Postural stability, Bone mineral density (BMD) Body composition	Brisk walking prevented the deterioration of postural stability with eyes closed, which can have a direct effect on reducing the risk of falls under worse spatial orientation and visibility.

6	Fong et al., 2017. Bone Mineral Density, Balance Performance, Balance Self-Efficacy, and Falls in Breast Cancer Survivors with and without Qigong Training: An Observational Study	Cross-sectional study, n= 93 subjects. 5-months intervention: Cancer survivors with Qigong training, Cancer survivors without Qigong training, Healthy control group	-	Each subject performed single leg stand balance test for maximum 60 seconds with 2 trials. Assessment involved: 1) Dual-energy X-ray absorptiometry (DXA), 2) Timed one-leg standing test, 3) Activities-specific balance confidence scale, 4) Face-to-face interview	Bone mass density (lumber spine, total hip, femoral neck and total radius), Single leg balance performance, Balance self-efficacy, Frequency of falls Fall History: Self-reported falls	Qigong may be a suitable exercise for improving the balance performance and balance self-efficacy of breast cancer survivors

Chapter 5

Discussion

5.1 Aerobic exercises and its effects on bone strength

The phase angle is a direct measurement of the functionality of our cell membrane. It has been linked to nutritional status for quite some time. The phase angle is influenced by the integrity of cell membranes and the number of cells in the body (Di Vincenzo et al., 2019). Therefore, a positive correlation between phase angle values and body cell mass has existed. Better health status will be identified with such a higher phase angle. As a result, skeletal maturity as measured by bone age may provide useful data in studies of phase angle determinants in adolescents. According to Koury (2018), bone age was used to determine skeletal maturity using the Tanner-Whitehouse 3 process (TW3), which was based on X-ray measurements in 13 bones of the left hand. The X-ray radiation dose was in the range of 0.003–0.007 rads, which is around 5% of the annual dose permitted. The discrepancy between the dates of birth and the radiograph was used to measure chronological age (decimal age). Skeletal maturity refers to the size, shape, and degree of mineralisation of the epiphyses and physeal plates of bone in order to determine their proximity to full maturity.

Based on the skeletal stage measured as the difference between bone age and chronological age, both in years, the participants were categorised into three maturity categories: “On time,” when the difference was between 1 and +1 years; “Late” (delayed) when the difference was 1 year; and “Early” (advanced) when the difference was > +1 year (Koury et al., 2018). Based on the study, it stated that the participants from the “Early” category have the higher phase angle values because they have higher BMI and fat-free mass due to biological maturation. Zinc is required for optimal growth since it plays important roles in the body, such as endocrine function and bone matrix structure. According to plasma zinc concentrations (< 10 μmol L^{-1}), 17% of male adolescent soccer athletes were zinc deficient in the current study, and the majority of these zinc-deficient teenagers were classified as the

"Late" category. As a result, it is understandable that increasing zinc uptake by muscle tissue and strengthening our bones can be achieved by aerobic activity.

A recent study reported that plyometric exercises had been safely performed in older adults aged ≥ 60 years (Vetrovsky et al., 2019). Plyometric training could increase bone mineral content and density, particularly in the femoral neck and hip. Gába et al. (2016) prescribed brisk walking among 58 women aged ≥ 50 years to measure bone mass. However, no substantial changes in the distal forearm or calcaneus bone mineral density (BMD) occurred after a brief intervention. To achieve notable bone improvements, the brisk walking intervention must be done for at least 3 to 12 months period. A recent study also recommended Qigong techniques, which originated in Chinese medicine and have been shown to be particularly beneficial in reducing BMD deficits at the lumbar spine, total hip, femoral neck, and total radius (Fong et al., 2018).

Although the mechanisms are unknown, mechanical loading generated by exercise encourages osteoblast formation and promotes bone strength. Osteocytes are cells that originate in the bone matrix, which will detect changes in mechanical strain and give signals to osteoblasts, which then stimulate bone development. When the intensity of applied loading exceeds that of usual loading, a bone formation (modelling) response develops. Even though in common weight-bearing exercise, it may increase the bone density due to the mechanical loading towards the bone where the load stimulates the bone-building cells as the bone matrix gently compressed. The ability of bone to sense the mechanical load could maintain and respond to the changes and increased muscle strain or other external trauma (Haelterman and Lim, 2019).

According to Yuan et al. (2016), mechanical stimuli change mesenchymal stem cells (MSC), osteoprogenitors, osteoblasts, and terminally-formed osteocytes. Mesenchymal stem cells have been mechanically loaded and found to have a positive effect on osteogenic

differentiation. While the increased lamellar bone development may be considered an adaptive response to moderate overloading, woven bone creation may be considered an overloading response (McBride and Silva, 2012). Mechanical signals such as fluid flow, dynamic tension, compression, and hydrostatic pressure all increase because of exercise. These mechanical cues stimulate osteogenic differentiation in MSCs while inhibiting adipogenic differentiation, which could be one of the reasons how exercise can prevent osteoporosis. This shows that exercise-induced mechanical loading can increase MSC differentiation into osteoblasts and/or chondrocytes. The Wnt/β-Catenin signaling pathway may be involved in bone remodeling generated by mechanical stress produced by exercise and physical activities. Wnt/β-catenin signaling, a highly conserved pathway through evolution, regulates key cellular functions including proliferation, differentiation, migration, genetic stability, apoptosis, and stem cell renewal (Pai et al., 2017).

5.2 Aerobic exercises and its effects on postural stability

According to Sciamanna et al. (2018), Working to Increase Stability through Exercise (WISE) was one experimental protocol which included strength, balance, and aerobic exercises to prevent fall-related consequences. Due to the loss of bone mineral density, these exercise interventions help to minimise the risk of falling and fall-related injuries by using American Heart Association (AHA) and the American College of Sports Medicine (ACSM) as the exercise guidelines. While another group of researchers focused on the benefits of aquatic training on the elderly to see if it may boost the underlying physical fitness component (Martinez-Carbonell Guillamon et al., 2019). Without outlining what type of clinical methodology was employed on the subjects, this study over-targeted a physiological component that should be able to prove the use of aquatic training as the best way in the hope of reducing risk factors for falls, and their goals were not even achieved. Another study examined the effects of aquatic exercise in reducing pain and improving balance in fibromyalgia patients (Rivas Neira et al., 2017). The activity had a significantly favourable outcome, whether it was done the water or on land, and it was also safe and effective, even if the evidence was of low quality because it was rarely done (Rivas Neira et al., 2017).

There are three studies which used the Tai Chi approach as their intervention exercises to enhance subjects' postural stability. According to Lin et al. (2019), 11 patients with mild to severe Alzheimer's disease completed the simplified Tai Chi 6-Form (STC6F) for 8 weeks were able to decrease the possibility of backward falls and, thus enhanced their balance. Another study has investigated the effects of individualised Tai Chi (iTC) on 50 subjects where only 20 participants performed iTC while the rest carried out the traditional Tai Chi (tTC) as the control group. Tai Chi, in general, helps to enhance balance and minimises the chance of falling. However, as compared to the tTC, the iTC appears to be more effective because the movements and exercise regime is easy and tolerable for elderly people, while also improving balance and increasing lower limb strength (Penn et al., 2019). Ultimately, a

study was undertaken on the superior effects of modified Chen-style Tai Chi (MTC) on senior people's balancing skills.

As compared to the 24-style Tai Chi (TC-24), MTC offers greater results in a variety of physical assessments, such as static and dynamic balance, leg power, and aerobic exercise capacity (Zou et al., 2019). In the original Chen-style Tai Chi, there are 56-form of movements and postures to be practiced overall whereby it is beneficial to promote health through the exercise. Silk reeling is a technique for coordinating body components to generate whole-body movement by alternating rapid and slow motions, as well as bursts of power. Modified Tai Chi is a more sophisticated movement pattern of Tai Chi that may include at least 18 postures derived from Chen-style Tai Chi. 24-style Tai Chi (TC-24) is a simplified Tai Chi that consists of 24 postures and takes around 6 minutes to perform. As a result, the more complicated Tai Chi movement patterns are (e.g. MTC), the better it is for improving cognitive function, balance, and aerobic capacity in the elderly (Zou et al., 2019).

Other researchers have discovered that 12 weeks of Nordic walking exercise has a positive effect on the gait parameters of women with osteopenia or osteoporosis (Ossowski et al., 2016). Lower extremity strength improved as a result of Nordic walking training, which was linked to improved postural control and functional mobility. Isokinetic muscle strengthening has an influence on osteoarthritis patients' risk of falling (Gezginaslan et al., 2018). The programme enhanced subjects' balance and proprioception abilities, as evaluated by the quadriceps and hamstring muscle ratio and average proprioceptive error because isokinetic exercise elevated Berg Balance Score (BBS) score. The BBS score was used to assess balance in the elderly. This programme may help to reduce the number of falls in those with a score of 20 to 40, which is considered a moderate fall risk. Nordic walking is a type of walking exercise that involves both upper and lower body motions with the use of a pole. Walking with specialised manufactured poles that push against the ground with each stride will stimulate the upper body. As a result, Nordic walking may have added benefits in terms of developing

muscular strength and aerobic performance. Because it supports the individual's body by minimising loads, the use of poles may help improve body stability while walking.

A recent study emphasising particular core stabilisation exercises in scoliosis patients found that as the lumbar rotation reduced between pre and post-treatment, the effects were significantly greater (Gür et al., 2017). With a scoliotic curvature of less than 25°, the spine was able to maintain stability as the spinal muscles managed to fix the deformity. Furthermore, a group of university students performed a research on spine stabilisation exercises, which found that the regimen reduced the tendency to fall by increasing the subjects' spinal posture and postural stability (Toprak Çelenay & Özer Kaya, 2017) . Then according to Areeudomwong et al. (2019), it was a study on Thai Boxing Dance (TBD), the intervention group gained the static and dynamic balance when their eyes were open. It may be prompted by an elevation in lower limb muscular strength and a decrease in postural stiffness during the exercises. By practising aerobic exercise, age-related problems such as reduced postural stability with eyes closed and anxiety or fear of falling while exercising can be resolved (Areeudomwong et al., 2019).

Another three studies demonstrated the effect of aerobic exercise on bone strength and postural stability. Vetrovsky et al. (2019) demonstrated that plyometrics can improve both static and dynamic postural stability which can lead to better balance during daily activities. Plyometric training is a counter-movement jump that incorporates weight-bearing and impact exercises with the use of the stretch-shortening cycle, which are both beneficial in increasing bone mineral density and lowering the risk of fractures in the elderly. During plyometric training, rapid force reabsorption and production are trained, which is very useful in a situation where an individual has almost tripped and has been struggling to regain their body stability. As a result, elderly people’s risk of falling and fear of falling may diminish, leading to improved levels of regular physical activity and decreased disability. Gába et al. (2016) clarified that from three parameters used to determine postural stability, only in the mean center of pressure

(COP) velocity in the anterior-posterior direction with eyes closed was the effect of brisk walking (BW) established. The other parameters cannot be achieved successfully due to the insufficient study span.

As stated in Fong et al. (2017), the one-leg stand test (OLST) revealed that qigong-trained breast cancer survivors performed better in their daily life than their non-trained peers. As a result, qigong may be a good exercise for breast cancer survivors to improve their balance performance and self-efficacy. Qigong is a weight-bearing, mind-body activity that extensively used a self-care approach for coping with the adverse effects of traditional cancer treatments and enhancing cancer survivors' bio-psychosocial health which is widely accepted by people in Chinese communities. With the involvement of a coordinated system of body-posture, slow-flowing movements, meditative relaxation and deep rhythmic breathing control, Qigong's participants learn and practice how to synchronise physical movements with breathing techniques until each posture is done perfectly (Chan et al., 2012). Once they have mastered the form, they need to identify the subtle flow or fluctuation of energy within the postures, movements, breathing patterns and transitions whereby it is also known as moving meditation. Qigong includes postures that are held for extended periods of time which are actually used to strengthen the limbs and promote the flow of energy known as still meditation.

5.3 Recommended aerobic exercise to improve bone strength and postural stability for different populations

Intervention time and the target groups, on the other hand, proved to be a barrier in terms of achieving both aims. Therefore, while deciding on the length of an intervention programme for future trials, researchers should keep this in mind so that the outcomes fit the demand. Variations in the amount, frequency, level, and nature of the physical activities may influence the length of interventions to be inadequate to satisfy the goals. However, increasing the duration of exercise might reduce people's willingness to engage in the activities for a longer time. For instance, walking for 30 minutes five times a week has been shown to be favourable, but not when the duration is increased up to 60-90 minutes. Among all those training methods, plyometric, brisk walking, and Qigong exercises are three types of aerobic exercise that are indicated to improve both bone strength and postural stability. However, there were some modifications used for different target groups.

In accordance with American College of Sports Medicine (ACSM) guidelines, it is advised for healthy adults aged 18-65 to engage at least 20-60 minutes per session of aerobic, resistance or neuromotor exercises (American College of Sports Medicine, 2018). It was reasonable to do 30 minutes of moderate level aerobic activity five days a week or 20 minutes of severe intensity aerobic exercise three days a week (American College of Sports Medicine, 2018). While physically active children and adolescents should engage in 60 minutes of moderate-to-vigorous intensity physical activity per day (e.g. aerobic, resistance, and bone strengthening exercises) or 8-15 submaximal repetitions of resistance exercise at least three times per week to specifically enhance bone health (American College of Sports Medicine, 2018). The best exercise prescription that could be suggested for healthy individuals is a combined exercise (e.g. strength, balance and walking exercise) which have been applied in one of the articles reviewed (Sciamanna et al., 2018). to exercise about 30-minute each session for two times per week on strength exercise, 20-minute per session three times per

week on balance exercise and walking exercise for at least 4500 steps per session to reduce all-cause of mortality.

Other than that, Tai Chi has become the most popular exercise that has been prescribed for the elderly. According to the eleventh edition of the American College of Sport Medicine's exercise guidelines, elderly individuals should engage in neuromotor exercises such as tai chi, qigong, and yoga (American College of Sports Medicine, 2018). Coordination, resistance, proprioception, and flexibility were all included in the neuromotor exercises (American College of Sports Medicine, 2018). When practised for 20-30 minutes two to three times a week, it is beneficial to develop individual balance, agility, muscle strength, and may also minimise the risk of falls and fear of falling (American College of Sports Medicine, 2018). To prescribe exercise for the elderly population, it is suggested to practise Tai Chi for about 30-minute per session for three days per week (Penn et al., 2019) or about 45-minute per session for two days per week (Lin et al., 2019). Compared to the modified version, Traditional Tai Chi appeared to be more effective because the movements and exercise regime is easy and tolerable for elderly people, while also improving balance and increasing lower limb strength.

After reviewing the types of diseases, the articles for patients can be split into two groups: those who have cancer and those with musculoskeletal disorders. According to the American College of Sport Medicine's guideline, a multimodal exercise programme incorporating cardiorespiratory, resistance, flexibility, and neuromotor exercise shows positive results to people with musculoskeletal diseases (e.g. back pain, fibromyalgia, osteoarthritis, osteopenia and scoliosis) (American College of Sports Medicine, 2018). Meanwhile, cancer patients were encouraged to perform aerobic exercises with a volume of 30 minutes per session of moderate intensity three times per week, or two sets of 12-15 repetitions of moderate resistance exercise two times per week, or a combination of the two doses, to eliminate cancer-related fatigue among the patients group (American College of Sports

Medicine, 2018). Therefore, the best exercise to be prescribed regardless of their age group and types of disease they facing through is brisk walking. This exercise could be classified as a moderate intensity; and it is recommended to be performed about 30-minute per session five times per week. In addition, it could improve the patients' quality of life, and also beneficial for strengthening bone and enhancing their postural stability.

5.4 Limitations of this review

This scoping review examined publications up to 2021 and only those in the English language were considered. Hence, there is a possibility that few related publications may have been missed. This happened due to a lack of source of reference from the previous studies and researchers only limited the study on the selected scope of research rather than other parameters. Therefore, it was quite hard to justify the findings since the evidence provided is very limited and not reliable.

Chapter 6

Conclusion

This scoping review generally shows that aerobic exercises are beneficial to improve bone strength and postural stability, particularly among three different populations. There were several aerobic exercises that can be prescribed to prevent injuries and improve quality of life.

Brisk walking, plyometric and Qigong exercises had been shown to improve bone strength including bone mineral density and bone mass as well as postural stability simultaneously. It is found that zinc uptake by muscle tissue cause changes in bone strength when combined with a soccer training exercise. Enhancements in postural stability could reduce the risk of falling after practicing varieties of aerobic exercises such as walking exercises (e.g. Brisk walking), Thai boxing dance, aquatic exercises therapy (water-based exercises), resistance and strength exercises, stabilisation exercises and also few forms of Tai Chi exercises. The positive outcome in postural balance performance can be found either in static or dynamic exercise. It is found that elderly individuals and patients groups are prone to have bone problems due to the decline of bone mineral density (BMD) related to the aging-related factor and the stability of body postures. Thus, our findings had identified the types of exercise that enhances postural stability such as aquatic exercise, resistance and strength exercise and Tai Chi.

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