Resistance training and its improvement on passive and active range of motion and performance within young adult female jazz dancers: a literature review and intervention study

Resistance training and its improvement on passive and active range of motion and performance within young adult female jazz dancers: a literature review and intervention study.

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Abstract:

Resistance training programmes within dance have been thoroughly researched in the genres of ballet, contemporary and modern dance. There is a gap in the research on the style of jazz dance which inspired the current literature review and intervention study. The literature review investigated whether strength, range of motion, and performance improved using resistance training programmes for a dance research population. The intervention study identified and evaluated strength, range of motion and performance improvement using a six-week pre- and post-testing resistance training intervention on a small young adult female jazz dance population. The literature review used four databases: Google Scholar, SportDiscus, PubMed and Medline. MeSH search words included '"range of motion"', 'hip flexion', 'performance', 'resistance training', 'strength training', 'flexibility', 'dance*', 'ballet', 'jazz', 'modern dance', 'active', 'passive'. Inclusion criteria were studies published in the English language; dated between the earliest date found 1990 and the current year 2024. The study participants were either in full-time training at pre-professional dance schools or university courses, or professional dancers aged between 16-35 years; research also needed to have more than 10 participants from any dance genre or aesthetic sports such as gymnastics. Exclusion criteria consisted of non-dance or non-aesthetic sports participants; any of the words range of motion, flexibility, strength, or dance performance were not included within the study as the main dependent variables. Conference proceedings or abstracts were excluded as well as if the research did not include intervention-style testing (pre-post-testing). Fifteen research papers met the inclusion criteria. Each of the included research papers was assessed on methodological quality and reliability using the Kmet Quality Tool Assessment and the papers scored between 14-23 out of 28. An intervention study was carried out and the participants were randomly assigned into an experimental group with twelve participants (age: 21.5 ± 1.55 years, height: 166.32 ± 3.93cm, weight: 57.31 ± 3.88kg) and a control group with ten participants (age: 20.8 ± 1.23 years, height: 166.31 ± 4.46cm, weight: 60.25 ± 8.49kg). The intervention group had to complete the six-week strength training intervention alongside their usual dance training schedule. The current intervention study added the strength, range of motion and performance results into Python 3.12 (64-bit) and found a P value of 0.0001, showing a significant positive effect in strength, active and passive range of motion, and performance within a small young adult female jazz dance population after using a resistance training programme intervention and formed a positive H1 hypothesis which was accepted. Similar limitations of the two papers were the researcher's knowledge, and the narrow scope of the jazz dance style and it was suggested that other genres not regularly tested should be looked into. Overall, the literature review and intervention study findings show that resistance training programmes positively affect a dancer's strength, range of motion and performance.

Key Words – dance, jazz dance, strength training, resistance training, flexibility, range of motion (ROM), performance.

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Chapter 1: Introduction

Over the past few decades, extensive research has developed an understanding of how resistance training (RT) positively impacts dance performance, particularly in the ballet, modern and contemporary dance genre [1, 2]. The inclusion of RT has proven to be a critical asset in enhancing dance performance [3]. As a result, dancers from various backgrounds are now incorporating RT into their programmes due to its well-documented benefits [3]. However, there is scarce research addressing the potential improvements within jazz dance performance (as opposed to ballet and contemporary) and improving a dancer's range of motion (ROM) [4].

The way to develop these potential improvements is to complete thorough research within the genre of jazz dance such as incorporating various RT programmes like strength training, Pilates training, and Whole-Body Vibration Training (WBVT) into a dancer's training schedule [2, 5, 6]. The benefits of RT have been tested on many dance genres such as ballet, modern, contemporary, Latin American, and aesthetic sports such as gymnastics, but little research has been done within jazz dance [3]. The current researcher will look into rectifying the gap by completing a literature review and an intervention study on whether RT positively improves performance and ROM within jazz dance, which has already been established within other dance genres [3, 7]. Furthermore, the introductory chapter will provide the context of background information and supply the research problems, aims, objectives, questions, and significance of the current studies.

1.1 Dance

Dance is a performance art [8] which involves movement and rhythm in a piece of music. To create dance, a choreographer is sometimes used to produce a well-thought-out collection of movements (or a motif) for a performance, often made with a theme or idea in mind [9]. Males and females can interact and participate in dance and there are various genres, such as ballet, modern, contemporary, jazz, street, bhangra, Latin American, and many others, that are practiced. Within the current dissertation, the jazz dance genre will be at the research's forefront. Similarly, ballet, modern and contemporary dance, as well as some aesthetic sports such as gymnastics, will be touched upon.

The earliest depictions of dance were in ancient Egypt which were formed on the walls of tombs [10]. Other eras such as seventeenth-century France used dance for entertainment and social aspects [8]. For example, dance was used in the settings of the court and theatre where the dance movements were similar in style. In contrast, in the nineteenth century, the ballrooms and theatres had opposing dance movements for social and entertainment purposes [8, 11]. Throughout the history of dance, artistic movement has been used for celebrations, religious ceremonies, entertainment and social aspects. Dance today is still used for entertainment in many theatrical performances and parties and is now depicted also in, TV shows and films as well as social media [8].

Compared to previous years, dance nowadays uses different technologies to enhance entertainment and the extravaganza of dance by using audio, camera techniques and special effects to create immersive performances for an audience [8]. Just like many years ago, costumes staging, and lighting can help enhance a

dance performance to entertain audiences alike [8]. In addition to the entertainment and social side of dance, within recent decades, dance has been linked to science due to its complex technical movements and training regimes [12, 13].

Dance can be linked to science due to the research on how a dancer's body moves, how interventions can be incorporated into training and how science can support dance. For example, many research papers are looking into the benefits of dance and how dance relates to performance, art and the sciences. Within the scientific research for dance, various researchers have looked into parameters such as ROM, strength, and performance to view whether a dancer's ROM and performance may be affected overall [3]. Not only this, but scientific dance research has also helped broaden the understanding that training in dance can partake in scientific adaptations to improve the overall performance of dancers [2, 3, 14-17].

The thesis is focused on jazz dance as there is a dearth of scientific literature focusing on this genre [3]. A description of jazz dance can be found in Appendix 1 which displays more information on the style. Whilst looking into RT and its improvements on dance, many papers focussed on dance styles other than jazz dance such as ballet, modern, and contemporary [3, 18-21]. There is less scientific research within the genre of jazz dance meaning there are fewer findings with ROM, performance, and strength considering that jazz dance training is a part of theatrical and educational fields [3] and should be researched. Considering there is less scientific research within the genre of jazz dance [3] compared to ballet, modern, and contemporary, showing a gap in the research for the style of jazz dance. The current researcher finds it necessary to develop research within this style for this dissertation. The researcher is passionate about the style of jazz dance after falling in love with the style in their dance school and then again at college before completing scientific research on the style at university.

1.2 Resistance Training within Dance

Resistance training is defined as exercise that uses machines, resistance bands, and free weights to cause the muscles to contract under external resistance [7]. The end goal of RT could either be muscular strength, endurance, or power improvements [28, 29]. Muscle hypertrophy is a product of RT and is important within training and is defined as the increase in the size of individual muscle fibres [7, 30, 31], some sports may benefit from hypertrophy as well as dance. Muscle hypertrophy can improve strength, endurance and power which are essential for various dance styles such as ballet, modern, contemporary and jazz [3, 32].

There are multiple elements of RT that dancers can focus on such as muscular strength, muscular power or muscular endurance. Muscular strength helps improve the amount of force a muscle can exert [30] and is beneficial for dancers to focus on building strength within specific muscle groups [32]. Muscular power is the ability of your muscles to exert force quickly [30] and improves strength and speed which allows dancers to perform movements with control and precision. With more control and precision, dancers improve their dynamics within certain movements such as jumps [33]. Muscular endurance is defined as the ability of which muscles can sustain repeated contractions over an extended period [34]. In dance, higher muscular endurance is beneficial so muscles do not fatigue during dance training or

performances [34]. Although all the goals for RT are essential for dancers, this current dissertation will be looking into muscular strength and maximal strength as muscle hypertrophy plays a part in improving the ability to execute dance movements with control and precision. Stronger muscles can help maintain alignment and balance which are elements of dance technique and overall can improve performance [3, 32]. To have maximal strength, this can help improve a dancer's performance and ROM which is beneficial for dancers [7]. Other benefits of RT are injury prevention and rehabilitation, and general fitness improvements and is used within competitive sports training as well as cosmetic training such as bodybuilding. Overall, the uses of RT are broad and can be used within day-to-day settings like the gym or scientific and artistic research [28].

In resistance training, maximal strength is used for muscles to produce the most amount of force that one muscle or multiple muscles can perform in a single effort through muscle contractions [43]. One repetition max (1RM) exercises are used across resistance training exercises to test and measure a participant’s maximal strength [7]. It allows the person to lift the heaviest weight they can for one repetition [44]. Maximal strength has been chosen out of speed-strength and strength-endurance as maximal strength may be beneficial for dancers to improve on parameters such as ROM and performance as found in some research papers [2, 7, 45-47]. Maximal strength can help improve performance parameters such as strength and control which are crucial for various dance genres [48]. It can also be noted that optimal muscular strength is beneficial for dancers [7], so, maximal strength will be focussed on in the current dissertation and will be the main independent variable.

Throughout this dissertation, strength is a term that will be used alongside the topic of RT. Strength has been used as a term instead of hypertrophy as there is a subtle difference that the researcher wishes to focus on. Hypertrophy focuses more on the aesthetics within RT by increasing muscle volume [16, 31, 35], which yes, dance skills involve aesthetic performance but, the current dissertation is looking into overall performance rather than aesthetics so therefore hypertrophy will not be focussed on. The reason for why can be found in Section 1.4. The definition of strength is how much force your muscles can produce to overcome resistance [36]. Strength will therefore be used instead of hypertrophy due to the relevance of strength relating more to the current study. The increase in muscular force is needed within dance to improve technical movements such as jumps and leaps but also helps with balance-focused movements such as pirouettes and the development of better ROM [37]. Power has also not been used as a term within this dissertation because this focuses on the duration the muscle takes to overcome resistance [38] which is not a focus of the current study. The terminology focus of the current dissertation is purely on maximal strength and how much force the muscle can produce. Within dance, strength is important for executing strong and powerful movements within dance routines [39-42]. By focusing on strength, dancers can enhance their performance quality and improve their overall capabilities within the studio and on-stage [39-42].

Considering the broad use of RT, researchers in dance incorporate RT in dance styles such as ballet due to its many benefits on performance, strength, and ROM [3, 32]. Resistance training can be used alongside a dance training schedule [3]. Doing

so can lead to improvements in technique, strength, ROM and overall performance to improve their performance for shows and auditions which is imperative for dancers [33]. Resistance training is slowly being incorporated into dance styles such as ballet, modern, and contemporary within dance training. Styles such as jazz dance are less researched and have less support within the benefits of RT on jazz dancers compared to the styles of ballet, modern and contemporary [3, 49]. Because of the gap in research, this dissertation will focus on whether RT can improve jazz dancers' training, strength, ROM, and performance, this can be viewed in Section 2.

1.3 The Importance of Passive and Active Range of Motion within Dance Training

Range of motion is used within all movement to a lesser or greater extent and is used within various sports, aesthetic sports, and performing arts [50]. Range of motion is defined as the limit of a body part that can move around a joint or fixed point [50]. Within the topic of ROM, there are two types, which are trained within dance training one being active ROM (AROM) and the other being passive ROM (PROM) [42, 51]. The definition of AROM within literature is the activation of muscles without external assistance to perform joints comfortable end range of motion [42, 51]. Compared to this, PROM is described in the literature as having assistance (such as a barre, hand, floor, or wall) to ease the joints into their comfortable end range of motion [42, 51]. Both AROM and PROM are important in dance training as there is a high demand in various dance styles for dancers to have high ROM, especially in the hip joints to help the lines of legs appear more aesthetic to the audience [52]. In most styles of dance training (such as ballet, modern, contemporary, and jazz dance), ROM is considered essential for dancers and is beneficial for performance technique; training ROM helps prevent injury and improves aesthetic performance [51].

Jazz, contemporary, modern, and ballet all have ROM infused within their styles [20, 22, 23, 25]. It is an essential part of dancing for various reasons such as performance [3]. Range of motion has multiple benefits, one benefit is it improves the aesthetic lines of the body [18, 53]. Another is that ROM can help improve a dancer's turn which is a basic movement in many dance styles [22, 23, 54]. Therefore, ROM is important in many styles of dance such as ballet, contemporary, modern, and jazz. The movements used in jazz dance (such as kicks), ballet (such as leaps), and contemporary (such as floorwork), need a high ROM within the legs to carry out certain movements listed as well as many other movements [20, 22, 23]. The higher the standard of ROM the better improvement in professional persona which can advance many dancers in their career [53]. Many dancers see a higher ROM as an advantage to be more flexible so that they can gain professional benefits over other competitors [53]. Hence, being more flexible to their end ROM is an essential part of being a dancer [20, 22, 25].

To balance strength and ROM, dancers can incorporate a well-rounded training programme that includes both RT to build strength and stretching exercises to improve AROM and PROM [3, 51, 55]. Resistance training helps build muscle strength which is essential for executing powerful movements [2], while stretching exercises help maintain or increase ROM, allowing a dancer to move with ease. Dancers need to strike a balance between strength and ROM to achieve optimal performance [3]. If strength and ROM are both improved, a dancer's overall

performance is inevitably improved [3]. The research in which has been completed on RT and ROM has mostly been completed on contemporary, ballet and modern, little research has been completed on jazz dance [3, 7, 47]. The aims, objectives and hypotheses of the current dissertation aim to fill the gap within the style of jazz dance, this can be viewed in Section 2. The topic of range of motion in the current dissertation is one of the dependent variables that will be researched alongside performance.

1.4 Dance Performance

Performance as a whole within dance focuses on visual aspects of the body adding artistry, and expressions to create an emotional response to an audience [56]. Performance also allows a dancer to express their individuality and is a way for dancers to communicate to the audience without words [56, 57]. Dance performance can evoke feelings and create a powerful experience for both the performers and the viewers [57]. Therefore, a dancer's overall performance is not only important for the dancer but for the audience too [57]. In dance research, performance knowledge continuously evolves and is essential to improving a dancer's skills [20, 58].

A dancer's overall performance refers to a dancer's general skill level, technique, artistry and ability to convey emotions through movement [59, 60]. On the other hand, performance enhancement focuses on specific strategies and techniques used to improve a dancer's performance, such as RT, flexibility training and refining specific dance movements [3, 61, 62]. So, while overall performance is about the dancer's holistic abilities, performance enhancement is more targeted towards improving specific aspects of a dancer's skills. The current researcher will be looking at performance enhancement within ROM and RT to gain an understanding of the overall improvement of a dancer's skill. Aesthetic performance within dance will not be used throughout this dissertation because it focuses on the message or story of the dance by using facial expressions and artistry, not using everything as a whole like overall performance [63]. Therefore, overall performance will be used instead of aesthetic competence as another main dependent variable of the current research dissertation.

Considering how important performance is to a dancer's improvement, there is no universal scoring system for performance in any dance style [64]. Instead, multiple different scoring systems that can measure different aspects of performance in dancers, Scoring systems such as the PCEM scoring system [58] looks at the alignment of the body, stabilisation, energy, articulation of the limbs and movement skills such as direction changes, balance, levels, speed and dynamics. Other research can focus on more specific testing such as scoring dancers on their jumping ability [46] Others have tested on overall aesthetic competence and technique within dancers [47]. As discussed, many scoring systems within dance can be used for various focuses and there is not one system that must be used throughout dance so it can become difficult for all dancers and judges to agree with the scoring system of performance in dance which may create bias [65].

As a whole, ROM, RT and overall performance are interconnected aspects that contribute to a dancer's abilities and artistry [3]. Improving ROM such as AROM and PROM through using an RT programme can help to enhance a dancer's ROM and strength which ultimately leads to better performance quality [66]. When these elements work together, dancers can execute movements more effectively, with

power and precision, elevating their overall performance on stage [33]. The interconnected aspects of ROM and RT to improve strength on a dancer's overall performance have less research within the jazz dance style as most research is within the genres of ballet, modern and contemporary dance [3, 20, 39, 49, 61, 66-69]. Due to the gap in research for jazz dance, the aims, objectives, and hypotheses of the current dissertation can be viewed in Section 2 which aims to fill this gap.

Chapter 2: Aims and Objectives

Given the lack of research regarding RT and its developments in jazz dance, this study will aim to identify and evaluate the improvement that RT can provide for dancers on various parameters. The literature review will aim to be a comprehensive analysis of existing research on the topic of RT usage within dance to provide a solid foundation for the intervention study. From the knowledge in this literature review, the intervention study will involve implementing a specific RT programme tailored for young adult female jazz dancers to observe its effects on their strength, ROM, and performance.

The first objective is to identify and evaluate strength, ROM and performance using RT programmes on the dance research population. This will be completed via a systematic literature review.

The second objective is to identify and evaluate the effect of an RT intervention programme on strength, ROM and performance using a young adult female jazz dance population. This will be completed via a six-week intervention study.

The current research has two possible research hypotheses:

Null Hypothesis (H0) – Resistance training has no significant effect on the passive and active range of motion and performance in young adult female jazz dancers.

Alternative Hypothesis (H1) – Resistance training has a significant positive effect on the passive and active range of motion and performance in young adult female jazz dancers.

2.1 Research Problem

As mentioned, RT within dance is critically important for the improvement of a dancer's overall performance [2-4, 70]. Numerous studies have investigated the importance of RT programmes and the improvements made to enhance a dancer's overall performance skills [3, 20, 39, 49, 61, 66-69]. However, these studies have looked into many other genres except for jazz dance when it has been established that jazz dance is popular in various educational and theatrical training facilities. Due to there being fewer research papers on the topic of how a jazz dancer's overall performance and ROM can improve from the implementation of RT programmes, there is a gap in research within this aspect of dance science literature.

As a result, the existing research is inadequate for jazz dancers whose essential knowledge of skill improvement is rapidly changing, as it assumes a slow pace of knowledge development on RT. Jazz dancers therefore find themselves ill-equipped with the knowledge and performance skills needed to improve themselves as

dancer. The current research study will contribute to the body of knowledge on RT and its development of understanding of ROM and performance skills within dance research where the knowledge of performance enhancement is constantly evolving. The current study will help address the current shortage of research and progress the knowledge within this field. This paper intends to carry out a literature search on previous research on the topics of improving performance skills, adapting a dancer's ROM, or improving a dancer's strength by using RT interventions. The second part of the paper will be an intervention study viewing whether using an RT programme helps improve strength, AROM, PROM and performance within jazz dancers just like it does within ballet modern, and contemporary dancers [2, 3, 68].

While researching the intervention study, the participants will be working with university dancers and dancers who have left university but continue to train in dance, these dancers are sometimes called pre-professionals. In the literature review, the dancers will be aged 16-35 as the researcher will be looking at a broad scope of participants as amateur pre-professional and professional dancers. In the intervention study, the dancers will be university students and pre-professionals aged between 18-24. Refer to Table 2 for the participants results in the systematic literature review. Please also refer to Section 4.1.1 which details participants methodology for the six-week intervention study.

Chapter 3: Literature Review

The integration of RT in dance has gained significant attention due to its potential benefits on dancers' performance and flexibility [64]. Understanding the impact of RT on dancers is crucial for improving their flexibility, strength, and overall performance. This literature review aims to explore the existing research and the current body of knowledge to provide insights into the effectiveness of RT as a supplementary practice for dancers, ultimately aiming to improve their strength, flexibility, and overall performance.

Based on the existing research, incorporating RT into a dancer's training regimen has shown positive outcomes in enhancing strength, flexibility, and overall performance. For example, one paper supplemented a weight training programme into dancers' training and their performance improved after nine weeks of weight training [2]. Various studies have highlighted the benefits of supplemental RT with exercises to improve muscular strength which is crucial for executing complex dance movements effectively [68]. A study which looked into the improvement of strength and jump height ability in dancers had improved in these areas after a nine-week plyometric or combined training programme was implemented into a dancer's usual schedule [71]. This integration of supplementing RT into dance has proven effective with dance styles such as ballet, modern and contemporary. This literature review will view all genres to provide a more inclusive understanding of whether supplementation of RT into a dancer's schedule can improve strength, flexibility, or overall performance within dancers.

Whilst completing the second literature search for this study, the researcher found a recently published systematic review and meta-analysis [64] similar to the current

literature review in this study. The differences can be viewed within the inclusion and exclusion criteria.

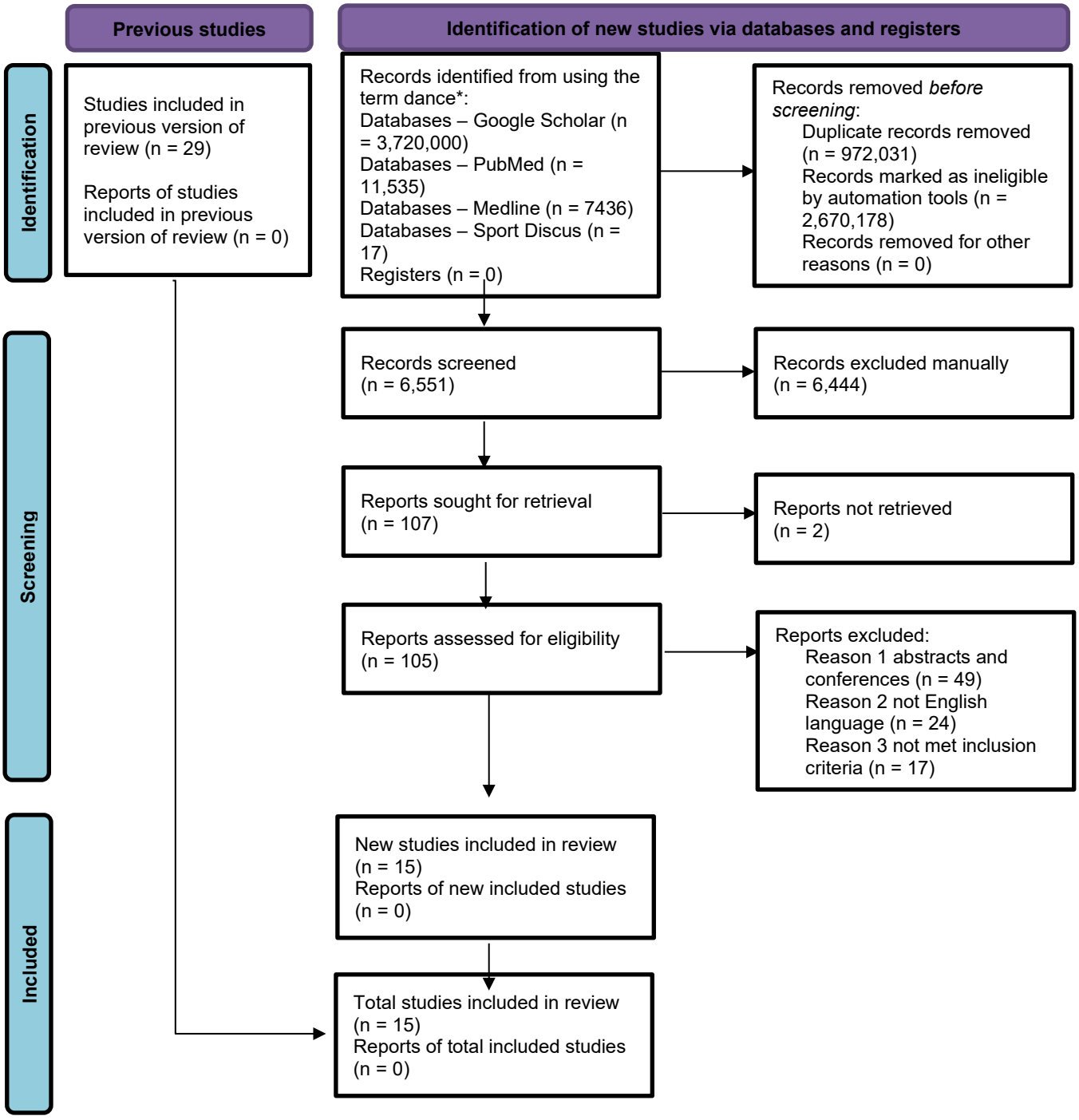
3.1 Literature Review Methodology

The current systematic literature review followed the guidelines from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [72] (Figure 1). A systematic literature review was used over a scoping and meta-analysis because the researcher planned to create context and show the gap which exists in the style of jazz dance. The researcher had learnt about the gap in Bachelor's so was passionate about adding research into this topic. A meta-analysis was not used as the literature would have required the methodology and outcomes to all be the same [73]. The researcher wanted to look into a broad idea of how strength training affects a dancer's, strength, ROM and performance which was similar to a scoping review. A scoping review was not used because the researcher felt it necessary to add more details from the literature to give more information context, not to keep the information broad but slightly more detailed [74]. In the end, it was decided by the researcher and supervisory team that a systematic review on its own would be best for this study. The first objective will be looked into for the current systematic literature review.

3.1.1 Search Strategy

The following four databases were used for the literature search: Google Scholar, SportDiscus, Medline and PubMed. These four specific databases were used as they have a larger range of dance-specific research papers to choose from. Boolean (AND), quotation marks (“”) and truncation (*) were used in each database to expand or narrow the search results for research. The four databases searched for research from the earliest possible date (1990) until the most recent at the time of the literature search (2024). MeSH search terms were used in the literature search and are displayed in Table 1. From the database Google Scholar there were n = 3,720,000 research papers found when the search started by just using the search word: dance*. PubMed, Medline and SportDiscus were more specific databases for sports and medicine research which helped to find research within the required dance field. The same search word of dance* was used in these databases and PubMed found n = 11,535 specific research papers; Medline found n = 7436 research papers whereas SportDiscus found n = 17 research papers at the beginning of the search (Figure 1). There was an initial search in 2021 which found research up to 2019. Doing a second search (2024) using the same MeSH search, there was one additional research paper which related to the inclusion and exclusion and followed the guidelines for PRISMA [72].

PRISMA 2020 flow diagram for updated systematic reviews which included searches of databases and registers only



*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).

**If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. Doi: 10.1136/bmj.n71

Figure 1: PRISMA Flow Diagram

3.1.2 Inclusion and Exclusion Criteria

The inclusion criteria consisted of:

- research published in the English language.
- papers dated between the earliest date found 1990 and the current year 2024.
- study participants had to be in either full-time training at pre-professional dance schools or university courses, or professional dancers aged between 16-35 years.
- research needed to have more than 10 participants from any dance genre or aesthetic sport such as gymnastics.

The exclusion criteria consisted of:

- Non-dance or non-athletic sports participants
- any of the words: ROM, flexibility, strength, or dance performance were not included within the study as the main dependent variables.
- if the papers were conference proceedings or abstracts
- if the research did not include intervention-style testing (pre-post-testing).

All screened research papers are displayed in Figure 1.

3.1.3 Study Selection

A previous search was completed in 2020 by the researcher and supervisory team and the final screening of studies was 29. A second screening was completed in 2024 by RJ and two independent reviewers (CW and MS). The initial number of MeSH search terms for each phrase was added from all databases and the total number of research papers was combined (Table 1). After retrieval of all studies from each database using the search term dance* (n=3,738,988), the duplicates were removed (n=2,972,209) by Endnote 20 (Clarivate) a database filterer and digital library. Title and abstract screening were carried out against the inclusion and exclusion criteria. The criteria were made by reviewers RJ, PD, and MW keeping the screening of research consistent within the team. Conference proceedings and abstracts were also removed alongside research that did not meet inclusion criteria or were not English language (n=90). Any differences within the search process were discussed between reviewers. After following the PRISMA Flow Diagram (Figure 1) for the screening process, full-text versions of the 15 included studies were attained and relevant data was extracted (Table 2). Endnote 20 (Clarivate) and PubMed Advanced Search Builder were used during the screening process.

Table 1: MeSH Search Terms

"range of motion" (n=4,611,436)	hip flexion (n=520,442)	performance (n=13,228,805)	resistance training (n=6,216,377)	strength training (n=6,311,105)	flexibility (n=5,844,184)	dance* (n=3,738,988)	ballet (n=899,497)	jazz (n=1,296,094)	modern dance (n=2,575,478)	active (n=15,005,790)	passive (n=5,159,161)
strength AND "range of motion" (n=4,336,326)	strength training AND hip flexion (n=178,463)	strength AND performance (n=7,122,509)	resistance training AND dance (n=896,221)	strength AND dance (n=2,460,851)	active flexibility (n=5,615,308)	jazz dance (n=406,396)	strength training AND ballet AND flexibility (n=38,054)	jazz dance (n=406,396)		active flexibility (n=5,615,308)	passive flexibility (n=1,732,383)
active AND passive "range of motion" (n=2,310,584)		strength training AND flexibility AND dance AND performance (n=212,048)		strength AND performance (n=7,122,509)	passive flexibility (n=1,732,383)	strength AND dance (n=2,460,851)	strength training AND ballet AND dance AND performance (n=69,437)			active and passive flexibility (n=2,521,249)	active and passive flexibility (n=2,521,249)
strength training AND dance AND "range of motion" (n=515,065)		strength training AND ballet AND dance AND performance (n=69,437)		strength AND flexibility (n=7,096,027)	active and passive flexibility (n=2,521,249)	strength training AND dance (n=1,480,516)				active AND passive flexibility (n=2,531,249)	active AND passive flexibility (n=2,531,249)
				strength AND "range of motion" (n=4,336,326)	strength AND flexibility (n=7,096,027)	strength training AND flexibility in dance (n=276,088)				active AND passive "range of motion" (n=2,310,584)	active AND passive "range of motion" (n=2,310,584)
				strength training AND hip flexion (n=178,463)	active AND passive flexibility (n=2,531,249)	strength training AND flexibility AND dance (n=324,088)					
				strength training AND dance (n=1,480,516)	strength training AND flexibility in dance (n=276,088)	strength training AND flexibility AND dance AND performance (n=212,048)					
				strength training AND flexibility in	strength training AND flexibility AND	strength training AND dance AND					

	dance (n=276,088)	dance (n=324,088)	flexibility (n=321,088)
	strength training AND flexibility AND dance (n=324,088)	strength training AND flexibility AND dance AND performance (n=212,048)	strength training AND dance AND “range of motion” (n=515,065)
	strength training AND flexibility AND dance AND performance (n=212,048)	strength training AND dance AND flexibility (n=321,088)	strength training AND ballet AND dance AND performance (n=69,437)
	strength training AND dance AND flexibility (n=321,088)	strength training AND ballet AND flexibility (n=37,354)	
	strength training AND ballet AND flexibility (n=38,054)		
	strength training AND dance AND “range of motion” (n=515,065)		
	strength training AND ballet AND dance AND performance (n=69,437)		

Table 2: Systematic Review Literature Search Information Results

Paper (Title, Author's, Year)	Study Design and Category	Participants (Gender, Age, Dance Style, Level of Experience)	Sample Size	Method/Intervention	Duration	Results	Outcome and P Value	Limitations	KMET Quality Tool Assessment
Some effects of supplemental Pilates training on the posture, strength, and flexibility of dancers 17 to 22 years of age E. L. Ahearn, A. Greene and A. Lasner 2018 [75]	Case Report Strength and ROM	Gender: Female dancers Aged: 16-21 Dance Style: Not Recorded Level of Experience: Post-secondary	20 Conditioning n=20	Two sessions of Pilates training Reformer (Beginner) - Week 1-3 Footwork - Toes, Arches, Heels, Tendon Stretch - 10x Hundred - 10x Leg Circles - 5x Frog - 6x Stomach Massage - Round(10x), Hands Back (10x), Reach Up (4x) Short Box - Round (4x), Flat (4x), Side to Side (4x), Tree (4x limber, 2x back) – [added week 2] Elephant - 5x to 8x Knee Stretch Series - Round (8x), Arched (8x), Knees off [prep added week 2] Running - 20x Pelvic Lift - 6x Reformer - Beginning Week 4 Footwork - Toes, Arches, Heels, Tendon Stretch (10x each) Hundred - 10x Short Spine - 5x Coordination - 5x Long Box - Pull Straps I/II – 3x, Backstroke - 3x to 5x [added week 6], Teaser Prep with no straps [added week 11] Short Box - Round (5x), Flat (5x), Side to Side (4x), Twist (3x), Tree (5x limber, 2x go back, 4x point and flex)	14 weeks, 2 sessions per week for 45 minutes each session	100% of participants agreed that the Pilates programme had improved their strength. 75% said they improved their flexibility. 45% agreed they improved their artistry. Hamstrings flexibility: improved from 19 inflexible average number of participants at pre-test to 6 at post-test.	The Pilates program may have a positive effect on flexibility, strength and posture P = Screening II to Screening III ($p < 0.001$).	Better postural and flexibility tests are required. Standardized samples and control groups should be included	14

				Long Stretch - Long Stretch (5x), Down Stretch (3x) [added week 7], Up Stretch (4x) [added week 11], Elephant (8x) Stomach Massage - Round (10x), Hands Back (10x), Reach Up (4x) Leg Circles - 5x Frog - 4x to 6x Knee Stretch Series - Round (10x), Arched (10x), Knees off (4x to 5x) Running - 20x Pelvic Lift - 6x to 8x Other equipment: Week 4 - added Wall Unit: Kneeling Chest Expansion, Push Thru Front, and Rolling Back Week 7 - added Wunda Chair: Push Down (4x), Pull Up (4x) Week 11 - added Wall Unit: Teaser with Push Thru (3x) Week 13 - added Large Barrel: Horseback (3x) Week 14 - added Wall Unit: Teaser with Push Thru - (3x) feet on the mat, Large Barrel: Roll Back Mat (Beginner and Intermediate): Hundred - 10x Roll Up - 5x Single Leg Circles - 5x Rolling Like a Ball - 6x Single Leg Stretch - 8x Double Leg Stretch - 8x Single Straight Leg Stretch - 8x Double Straight Leg Stretch - 8x Criss-Cross - [added week 2] - 3x with feet on the floor, week 3 with legs at the tabletop, [week 5] added legs increased reps to 5x to 6x Spine Stretch Forward - 4x to 5x [added week 3] Open Leg Rocker - 6x beginning with prep				

				Corkscrew - 3x each way - hips off [added week 12] 3x Saw - 4x Neck Roll - 2x to 3x [added week 3] Single Leg Kicks - 4x to 5x [added week 5] Double Leg Kicks - 3x to 4x [added week 10] Neck Pull - 5x [added week 10] Side Leg Kicks – F/B (5x), U/D (5x), Small Circles (5x) [added week 5], Bicycle (3x to 4x) [added week 7] Transitional Beats - 16x [added week 10] Teaser I - 3x each leg [prep week 2], Teaser 1 [added week 10] Can-Can - 3x [added week 11] Swimming - 10x [added week11] Leg Pull Down - 3x [added week 11] Leg Pull-Up - 3x [added week 11] Seal - 6x Push Ups - 3 sets [added week 5] Standing Chest Expansion, Zip Up Week 14 - added Magic Circle to Roll Up, Double Straight Leg, Neck Pull, Side Kicks, and standing exercises - Low, Mid and High 4x each					
Effects of supplemental training on fitness and aesthetic competence parameters in contemporary dance: a randomised	Randomised Control Trial Strength and Performance	Gender: Female Age: Conditioning: 27.0 ± 4.3 Control: 27.0 ± 7.9 Dance Style: Contemporary dancers Level of Experience: Preprofessi	N Total = 21 Experimental = 12 control = 9	6-week circuit and whole-body vibration training programme Materials: vibration platform, free weights, jump ropes and mats. 1h training session, 2x p/w. Warm up and cool down performed each session. Circuit training (CT) and WBV programme, 10 mins rest between training programmes. Supervised gym sessions by the same supervisor each time. Dance-specific CT programme designed with upper-body and lower-body exercises: 4x circuit, 10 stations with 10 exercises, as many reps in 30-secs each exercise: jumps with feet in parallel position (using a jumping rope), press-ups, bicep curls, triceps extension (with free	6-week intervention with 2 one-hour sessions	Conditioning (n=12) Press ups (n.min–1) pre-test: 29 ± 7.24 post-test: 37 ± 12.34. Standing vertical jump (cm): pre: 29.9 ± 5.81. post: 33.6 ± 3.38. Aesthetic Competence: pre-test: 38 ± 12.92 post-test: 43 ± 6.34. Control (n=9) Press ups (n.min–1) pre-test: 30 ± 6.29 post-test: 30 ± 2.12. Standing vertical jump (cm): pre: 30.3 ± 4.39. post: 28.5 ± 3.32. Aesthetic Competence: pre-test: 45 ± 6.22 post-test: 42 ± 3.34. (mean ±sd)	Whole-body vibration training improved aesthetic competence and fitness parameters for contemporary dancers $P < 0.05$ Repeated measures ANOVA: conditioning group - lower body muscular power (11%), upper body muscular endurance (22%), aerobic fitness (11%),	Effects of supplementary training over injury rate and severity should be researched	23

controlled trial M. Angioi, G. Metsios, E. A. Twitchett, Y. Koutedakis and M. Wyon 2012 [76]		onal and professional dancers		weights of 0.5 kg each), single leg squat, squats-jumps, heel-rises in dance first position, deep squats in dance second position, chest press exercises (with free weights of 0.5 kg each), and plank. 10-sec transition between each station. Total time including rest = 6 min 50 sec. WBV training programme adapted from [77]: 3 sets, 40-secs of 6 static positions: 1) squat position with feet in dance first position.; 2) plank position (elbow flexed on the floor and feet on platform); 3) lunge position (right and left leg); 4) press up position, 90° bend at the elbows; 5) calf position, feet in relevé (heel-rise) with knees slightly bent; 6) hamstring position, bent over at waist, with knees slightly bent and hamstrings tensed. 2 min rest, vibration frequency = 35 Hz and amplitude at 2.5 mm. Total sessions n = 2x p/w.			and aesthetic competence (12%) ($p < 0.05$)		
Effect of whole-body vibration training on lower limb performance in selected high-level ballet students G. Annino, E. Padua, C. Castagna, V. Di Salvo, S. Minichell	Randomised Control Trial Strength	Gender: Female Age: Conditioning: 21.0 ± 1.3 Control: 21.2 ± 1.6 Dance Style: Ballet Level of Experience: Full-time dance students	22 Experimental = 11 control = 11	Whole-body vibration training intervention, pre- and post-testing Vertical sinusoidal WBVs: Nemes LC device (Boscosystem, Rieti, Italy). Frequency = 30 Hz [63] 5-cm displacement; magnitude = 5 g to maximise WBV training effects. Sessions performed before ballet dance class. Sessions = 5x 40-secs; rest = 60-secs passive recovery; 3x per week (Monday, Wednesday, and Friday). Total = 24 sessions over 8 weeks. Vibration platform position: half-squat position (approximately 100°) with feet and knee rotated externally (i.e., demi-plie´ position). Dance shoes were worn.	8-week intervention and the tasks were completed 3 times per week	AP (W) Before Mean ± SD Experimental: 50kg: 258.7 ± 24.7. 70kg: 323.1 ± 45.9. 100kg: 271.5 ± 79.2. Control: 50kg: 282.8 ± 15.5. 70kg: 356.0 ± 46.9. 100kg: 352.4 ± 100.3. After Mean ± SD Experimental: 50kg: 280.7 ± 21.7†. 70kg: 340.4 ± 32.6*. 100kg: 320.4 ± 66.8†. Control: 50kg: 277.7 ± 26.3. 70kg: 376.6 ± 92.5. 100kg: 385.4 ± 56.4. (* $p < 0.05$. † $p < 0.01$.).	WBV training has positive outcomes on this population for knee-extensor explosiveness. $p < 0.05$–0.001 Post-training CMJ performance increased in E group (6.3 ± 3.8%, $p < 0.001$). E group showed significant ($p < 0.05$–0.001) leg-press power and velocity improvements	If progressive WBV training programmes are used this could improve strength, explosive strength and CMJ performance	23

a, O. Tsarpela, et al. 2007 [78]									
Effects of plyometric training versus traditional weight training on strength, power, and aesthetic jumping ability in female collegiate dancers A. C. Brown, T. J. Wells, M. L. Schade, D. L. Smith and P. C. Fehling 2007 [46]	Randomised Control Trial Strength	Gender: Female Age: Plyometric training: 20.3 ± 1.5 Resistance training: 19.3 ± 1.2 Control: 19.5 ± 1.0 Dance Style: Contemporary and ballet Level of Experience: Collegiate dancers	18 Plyometrics = 6 weight training = 6 control = 6	Plyometrics training and weight training Warm-up and cool-down were performed before both sessions if no dance class was completed beforehand. Control asked to participate in no additional training beyond dance classes. Weight training: sessions = 2x p/w; 30-45 mins p/session; 1 recovery day. Training sessions supervised. Asked to perform, 80% 1RM, 4 lower body exercises: decline leg press, calf raise, leg curl, and leg extension; 3 sets of 6-8 reps until momentary muscle failure; 1 min rest. When the subject completed 8 reps for 2/3 sets, weight was increased by 5% in the next training session. Plyometric training: sessions = 2x p/w; 30-45 mins p/session; 1 recovery day. 3 sets of 8 reps; 4 exercises for 96 touches (a jump or a foot contact with the floor) per session. Low-medium intensity with low-volume touches. Four exercises: depth jumps (stepped off a box into a squat, thighs parallel to ground, then jumped as quickly as possible to max vertical height), step-ups (stood with left foot on floor, right on box. Fully extended leg and landed back down on right leg, swapped legs after 8 reps), box jumps (two-footed countermovement hop from floor to box), and froggies (2-footed max horizontal hop similar to standing long jump); 1 min active recovery (walking). Intensity (how explosive jumps were) and height increased every 3 sessions. Encouragement and feedback are used for maximal effort in subjects. 6 inches box used for: depth jumps, step-ups, and box. Intensity increased (3-inch increase) at	6 weeks with 2 sessions per week	Plyometrics: Strength (kg): Leg Press: Pre: 183.3 ± 30.9. Post: 251.5 ± 39.4†. Knee Curl: Pre: 37.5 ± 4.0. Post: 40.9 ± 3.8. Knee Extension: Pre: 62.5 ± 9.1. Post: 57.5 ± 7.7. Subjective Evaluation: Feet point: Pre: 3.8 ± 0.6. Post: 3.8 ± 0.4. Overall Ability: Pre: 3.2 ± 0.5. Post: 3.5 ± 0.5. Weight Training: Strength (kg): Leg Press: Pre: 214.4 ± 61.0. Post: 282.5 ± 48.0†. Knee Curl: Pre: 34.8 ± 4.5. Post: 42.8 ± 3.4*. Knee Extension: Pre: 58.7 ± 6.5. Post: 61.7 ± 4.4. Subjective Evaluation: Feet point: Pre: 3.0 ± 1.2. Post: 3.6 ± 0.7*. Overall Ability: Pre: 3.0 ± 1.4. Post: 3.3 ± 0.9. Control: Strength (kg): Leg Press: Pre: 222.7 ± 65.0. Post: 229.0 ± 72.9. Knee Curl: Pre: 40.0 ± 5.7. Post: 40.9 ± 3.7. Knee Extension: Pre: 60.5 ± 10.1. Post: 56.5 ± 10.2. Subjective Evaluation: Feet point: Pre: 3.3 ± 0.1. Post: 3.9 ± 0.4. Overall Ability: Pre: 3.1 ± 1.2. Post: 3.8 ± 0.7. [†p < 0.01 (Significance within group, pre vs. post); *p < 0.05	Weight training and plyometrics training have a positive impact on dance variables. p < 0.05 Plyometrics: leg press strength (+37%, p < 0.01) WT: leg press strength (+ 32%, p < 0.01) leg curl strength (+ 23%, p < 0.05) WT: absolute mean anaerobic power (+ 6%, p < 0.05) vertical jump height (1.0 ± 0.8 in = 8.3%, p < 0.05) Plyometrics: subjective jump height (+ 14%, p < 0.05), weight training: subjective jump height (+ 22%, p < 0.01) and ability to point the feet while jumping (+ 20%, p < 0.05).	Increased study size and duration need to be researched on	23

				sessions 4 and 7. Froggies improved by explosiveness of jump, intensity increased every 3-weeks.		(Significance within group, pre vs. post)].			
The effect of classical ballet and contemporary dance training on hip extensor flexibility and strength in novice dancers: A pilot study S. DiPasquale and M. Wood 2017 [19]	Non-randomised Control Trial Strength and ROM	Gender: 21 females and 8 males Age: Experimental = 19.8 ± 1.1. Control = 20.4 ± 0.8. Dance Style: Ballet and Contemporary Level of Experience: College student Non-dancers and College student dancers.	29 Experimental = 22 control = 7	Dance training intervention using plyometric movements Intervention = 2x p/w for 11 weeks; 80 min classical dance training p/session. Live piano in every session. First 6 weeks = classical ballet: learned basic positions of ballet (feet and arms for 1st, 2nd, 3rd, 4th, 5th), barre warm up then centre, plyometric jumping (sauté), and travelling across the floor. Last 5 weeks = contemporary dance: learned basic movements and phrases from Limon and Graham techniques i.e. flat back positions, c-curves, falls to the floor, and plyometric jumping patterns (sauté jump).	11-week intervention with two sessions of 80-minute classical dance training per week. Also, the first 6 weeks were ballet and the last 5 were contemporary-based training.	Experimental: Hip extensor flexibility; Left (◦). Pre: 69.82 ±23.20. Post: 99.77 ±20.23. Hip extensor flexibility; Right (◦). Pre: 75.18 ±23.08. Post: 101.36 ±19.34. Knee flexor strength; Left. Pre: 4.23 ±0.61. Post: 4.73 ±0.46. Knee flexor strength; Right. Pre: 4.23 ±0.61. Post: 4.68 ±0.48. Hip ext, knee flex; strength; Left. Pre: 3.73 ±0.70. Post: 4.55 ±0.51. Hip ext, knee flex; strength; Right. Pre: 3.64 ±0.66. Post: 4.64 ±0.49. Hip ext, knee ext; strength; Left. Pre: 3.95 ±0.72. Post: 4.68 ±0.48. Hip ext, knee ext; strength; Right. Pre: 3.91 ±0.68. Post: 4.73 ±0.46. Control: Hip extensor flexibility; Left (◦). Pre: 75.57 ±13.06. Post: 85.43 ±11.28. Hip extensor flexibility; Right (◦). pre: 95.00 ±74.57 post: 102.00 ±86.43. Knee flexor strength; Left. Pre: 4.00 ±0.82. Post: 4.43 ±0.53. Knee flexor strength; Right. Pre: 4.00 ±0.82. Post: 4.43 ±0.53. Hip ext, knee flex; strength; Left. Pre: 3.86 ±0.90. Post: 4.00 ±0.82. Hip ext, knee flex; strength; Right. Pre: 3.71 ±0.76. Post: 4.00 ±0.82. Hip ext, knee ext; strength; Left. Pre: 4.00 ±0.82. Post: 4.29 ±0.49. Hip ext, knee ext; strength; Right. Pre: 3.86 ±0.69. Post: 4.29 ±0.49. Strength measurements rated on a 0–5 scale, 5 = full strength. *	Ballet and contemporary increase flexibility and strength in the population. Experimental: bilateral hip extensor flexibility ($p < 0.001$) and in right hip extensor strength ($p < 0.05$)	The sample size is inadequate and the control group and experimental should match in size for further research	19

						Significance = $p < 0.05$. ** Significance = $p < 0.01$.			
The effects of three months of aerobic and strength training on selected performance-and fitness-related parameters in modern dance students Y. Koutedakis, H. Hukam, G. Metsios, A. Nevill, G. Giakas, A. Jamurtas, et al. 2007 [47]	Randomised Control Trial Strength, ROM and Performance	Gender: Male and Female Age: Experimental: 20.1 ± 2.7 Control: 19.4 ± 2.1 Dance Style: Modern dance Level of Experience: students are all in the first of 3 years of training to be professional dancers	32 Female = 27 male = 5 Experimental = 19 Control = 13	Aerobic and strength training Intervention: one supervisor at all times. Individual plans were made for each participant. Aerobic training: 20–40 minutes of swimming, jogging, or cycling, 2–3x p/w for 12-weeks. Intensity = 70–75% MHR (MHR = 220 - age). Strength training (lower body): adapted from men's programmes [62] and women's [47]. 12-week intervention; 3x 50 min sessions p/w. Free-weight upper- and lower-body exercises were used. First 2 weeks: low-resistance = <70% of 1RM, with high reps. Later resistance increased by 15–20%, 3-4 exercises with 5-6 sets and 8 reps per exercise. Rest = 4 mins.	12-week, 2-3 sessions per week for 20-50 minutes each	Exercise group: dance test (points) pre: 73.9 (± 16.2). Post: 109.2 (± 21.3). Flexibility (°) pre: 125.5 (± 24.6). Post: 140.0 (± 23.4). Strength left and right leg (kg) pre: 90.6 (± 16.0). Post: 102.0 (± 17.4). Control group: dance test (points) pre: 76.0 (± 19.4). Post: 81.5 (± 11.8). Flexibility (°) pre: 123.2 (± 17.8). Post: 129.3 (± 17.2). Strength left and right leg (kg) pre: 94.1 (± 15.8). Post: 83.1 (± 11.2). *ANOVA = analysis of variance; NS = nonsignificant ($p > 0.05$).	The training programme improved dance performance, vo2 max, flexibility and leg strength. Improvements in vo2max and strength do not negatively impact performance. Dance-only will not help improve specific parameters. Need to incorporate training too. Significant increases in dance ($p < 0.02$), $V^{\cdot}$ O2 max ($p < 0.04$), flexibility ($p < 0.01$), and leg strength ($p < 0.001$) tests compared to controls	More research should be completed on outside training and the impact it has on dance performance	23
Thigh-muscle strength training, dance exercise, dynamom	Randomised Control Trial Strength	Gender: Female Age: 25.0 ± 1.3 Dance Style:	22 Experimental = 12 control = 10	Lower extremity strength training Adapted from men's training programme [62]. Intervention: free-weight exercises using hamstring and quadriceps, 12-weeks, 3x 50mins p/w. Low resistance exercises, high reps first 2 weeks - (<70% of 1RM).	12 weeks, 3 sessions per week for 50 minutes each	Experimental group: 16% increases in hamstring ($p > 0.001$) and quadriceps ($p > 0.001$) torque levels. No significant changes in the control group. Before and after the dance routine, both experimental and control had a 21% decrease in	Strength training programmes for ballerinas are effective specifically for their dancing. It works better on weaker dancers than on stronger.	Off-studio strength and power training should be looked into	23

etry, and anthropometry in professional ballerinas Y. Koutedakis and N. C. Sharp 2004 [61]		Ballet Level of Experience: full-time professional ballerinas		After: high resistance and low reps (>70% 1RM). Sessions: in the morning before dance class, 5–6 sets, 8 reps of 3–4 exercises each. Rest = 4 mins. Cybex isokinetic dynamometer (Cybex International, Medway, MA) was used to assess concentric peak torques of knee extensors (quads) and flexors (hams) in both legs, in a random order. Angular velocity = 1.04 rad·s21. On the dynamometer, subjects were without shoes, with hips and knees flexed at 80° and 90° angles. ROM between = 0° and 90° of knee flexion to prevent hyperextension and hyperflexion. Angular velocity control of the dynamometer was checked by counting the number of revolutions per/minute at 1.04 rad·s21. First familiarization period: 8 submaximal concentric knee extension-flexion cycles for each leg. After: 3 max extension-flexion contraction cycles for each leg performed. Rest = 5 mins. Exercise choreographed for muscle fatigue after 5 mins: repetitive jumping from first to second positions with port de bras. Arms starting in bras bas through to 5th, to 2nd, performed to a metronome = set to 76b·min21. The ballet master stopped when technical fatigue showed.		hamstring ($p > 0.001$) and quadriceps ($p > 0.001$) peak torques. After, strength training only the control group showed a reduction in torque ($p > 0.001$).	Experimental group: 16% increases in hamstring ($p > 0.001$) and quadriceps ($p > 0.001$) torque levels. Control: 21% decrease in hamstring ($p > 0.001$) and quadriceps ($p > 0.001$) peak torques. After, strength training only the control group showed a reduction in torque ($p > 0.001$).		
The effect of whole-body vibration on jump height and active range of movement in female dancers	Randomised Control Trial Strength and ROM	Gender: Female Age: Intervention: 22.0 ± 1.2 Control: 25.0 ± 5.9 Dance Style: Modern dance	20 Experimental = 10 control = 10	Whole-body vibration training Familiarization period: warm-up 5 mins of aerobic activities MHR intensity: between 120 and 160 bpm-1, 2 mins dynamic stretching (quadriceps, hamstrings, and calf muscles), 2 mins rest [63]. Vibration training: 8 sessions 2x p/w for 4 weeks. 2 days in between sessions for recovery. Intervention group: 30 seconds per position at a 35-Hz frequency. First 2 weeks: 30 seconds per position at a 35-Hz frequency last 2 weeks:	2 intervention sessions for 4 weeks	Intervention group: jump height (cm) pre: 43.2 ± 1.09. post: 45.6 ± 1.86*. right AROM pre: 99.9 ± 6.56. post: 117.5 ± 7.92*. left AROM pre: 101.4 ± 7.63. post: 116.9 ± 10.08*. Control: jump height (cm) pre: 39.4 ± 1.51. post: 38.8 ± 1.63. right AROM pre: 105.3 ± 3.78. post: 107.1 ± 3.57. left AROM pre: 105.9 ± 3.66. post: 107.9 ± 4.01.	WBVT improves jump height and active ROM without altering muscular aesthetics. ($p < 0.01$) intervention group vertical jump and active ROM	External load, vibration frequencies and the effects these have on muscular hypertrophy need further research	23

L. C. Marshall and M. A. Wyon 2012 [55]		Level of Experience: Full-time students		40 secs per position at 40 Hz [6, 63, 64]. Platform peak-to-peak displacement: 8 mm. 9 positions, each exercise completed, once statically, once dynamically: narrow and wide semi-squat (first and second position plié), high toe raise, pelvic bridge with back on floor and feet on platform, right leg leading lunge (with front foot on the platform), left leg leading lunge, a bent-over hamstring hold (90°), active hip flexor exercise on each leg (developpés – extension held for 2 secs with increase of external hip rotation on count 2). Positions were turned out. The control subjects completed the same exercises as the intervention subjects but on the floor without vibration.		*Denotes significance at p<0.05.			
The effects of an 8-week resistance training intervention on muscular strength, power, and body composition in Collegiate Female Dancers D.J. Sanders, T.D. Cardaci, B.A. McFadden, A.J. Walker,	Randomised Control Trial Strength	Gender: Female Age: Experimental: 19.3 ± 1.3 Control: 19.6 ± 1.3 Dance Style: Not Recorded Level of Experience: Collegiate dancers	16 Experimental = 8 control = 8	Participants split into either an upper- or lower-body resistance training programme. Control and experimental proceeded with usual dance training. Experimental performed additional RT 3× non-consecutive p/w for 8 weeks. Upper- and lower-body alternated sessions: 5-min warm-up; multi-joint exercises 3 sets, 10-12 reps; single-joint and abdominal exercises 2 sets, 12-15 reps. Rest = 90 secs. Upper-body: bench press, dumbbell row, seated dumbbell shoulder press, latissimus-dorsi pull-down, biceps, triceps, and abdominal exercises. Lower-body: back squat, barbell Romanian deadlift, barbell split squat, leg curl, leg extension, calf raises, and abdominal exercises. The programme had progressive overload: load was increased when subjects completed the rep-range with proper form. The initial load for squat and bench press was 65% 1RM (determined from pre-testing). Participants used their load understanding for exercises and load was adapted to perform the	8-week period with 3 sessions per week	1-RM squat (EXP=39.2±9.4 kg vs CON=8.1±5.5 kg; P<0.001) from pre- to post-test intervention. Experimental: Sqt1-RM (kg) pre: 59.2±13.5. post: 98.5±18.4*. BP1-RM (kg) pre: 32.7±8.3 post: 42.0±6.2*. Control: Sqt1-RM (kg) pre: 55.9±11.2 post: 64.0±12.1*. BP1-RM (kg) pre: 27.5±6.4 post: 28.7±4.8. *Denotes significant differences from pre- to post-intervention p<0.05.	Significant improvement in strength, no significant improvement in power but still improved. Strength EXP: (P<0.05). VJpower EXP: (P=0.07). regular waist: (P=0.025) hip: (P=0.034) decrease in regular waist girth CON: (P<0.05)	RT and nutrition should be looked into for optimising strength, power, and body composition	21

B.N. Bozzini, H.P. Cintineo and S.M. Arent 2020 [79]				required number of reps for that exercise; load increased after 2 reps performed after the prescribed set for exercise. Weight increases were upper-body: 1-2.5 kg and lower-body: 2.5-4.5 kg.					
The effects of supplemental weight training for ballet dancers M. A. Stalder, B. J. Noble and J. G. Wilkinson 1990 [2]	Non-randomised Control Trial Strength, ROM and Performance	Gender: Female Age: Experimental = 23.3 ± 4.3 Control: 20.4 ± 3.3 Dance Style: Ballet Level of Experience: College dancers	14 Experimental (weight training) = 7 control = 7	Resistance training Weight training: free weights and manual resistance; 3x p/w for 9-weeks. 3 sets, 10 reps, 10RM load performed for each exercise. Rest = 1 min; agonist muscle stretched for 30-sec. Exercises and stretches: seated leg press – quad stretch, calf raises – gastrocnemius stretch, hip adduction – frog position (sitting open leg stretch), hip abduction – pretzel stretch over a straight bottom leg, ankle push plantar and dorsi flexion manual resistance with ankle circles, plié and relevé turned out with free-weight and ankle circles then modified at 4 weeks to plié roll through to hyperextension at ankles with toes and knees flexed straighten knees and lower heels, knee-ups with torso twist supporting the weight of body off the ground with the arms with spine hyperextended at four weeks experimenter held ankles for greater resistance.	9-week intervention period with 3 sessions of weight training and practised ballet 4 days per week for 90 mins	Experimental: strength (kg): 115° leg extension: pre: 41.7[1] (± 4.2). Post: 43.9 (± 2.7). 130° leg extension: pre: 38.9 (± 4.6). Post: 41.0 (± 3.6). 150° leg extension: pre: 28.1 (± 8.2). Post: 31.4 (± 8.1). Plantar flexion: pre: 43.2 (± 1.8). Post: 44.5 (±1.1). Dorsi flexion: pre: 15.27 (± 4.4). Post: 17.2 (± 5.4). Adduction: pre: 16.1 (± 2.2). post: 18.6 (± 2.1) *. Flexibility (°): Anterior hip: pre: 121.9[1] (± 8.2). Post: 123.3 (± 8.6). Lateral hip: pre: 119.2 (± 11.9). post: 127.1 (± 9.8) *. Hip extension: pre: 33.8 (± 10.9) post: 33.3 (± 9.8). Plantar flexion: pre: 83.6 (± 10.5). Post: 82.2 (± 14.3). Dorsi flexion: pre: 17.5 (± 7.3) post: 18.1 (± 8.3). Ballet technique evaluations on a scale of 1-9: stamina: pre: 5.0[1] (± 1.7) post: 5.8 (± 1.8). Precision: pre: 4.6 (± 2.0). post: 5.0 (± 1.8) *. Performance: pre: 4.8 (± 1.8). Post: 5.0 (± 1.6). Averaged Score: pre: 4.8 (± 1.9) post: 5.3 (± 1.7) *. Control: strength (kg): 115° leg extension: pre: 41.9 (± 2.9). Post: 41.9 (± 4.0). 130° leg extension: pre: 39.5 (± 3.5). Post: 39.3 (± 3.5). 150° leg extension: pre: 27.0 (± 4.5). Post: 27.5 (± 5.0).	Weight training can improve leg strength, endurance and anaerobic power without causing aesthetic requirements for ballet. P < 0.05 in WT group for adductor strength, anaerobic power, lateral hip flexibility, precision and overall average performance ballet score.	Compare training modalities, cycling weight training programme and adding dynamic flexibility programme	19

						Plantar flexion: pre: 39.5 (± 3.1). Post: 41.86 (±3.9). Dorsi flexion: pre: 14.6 (± 1.9). Post: 13.7 (± 2.6). Adduction: pre: 17.0 (± 2.8). Post: 16.8 (± 1.8). Flexibility (°): Anterior hip: pre: 116.6 (± 6.9). Post: 118.0 (± 6.9). Lateral hip: pre: 119.0 (± 8.4). Post: 119.2 (± 5.4). Hip extension: pre: 25.7 (± 6.2) post: 28.6 (± 5.6). Plantar flexion: pre: 71.3 (± 12.1). Post: 69.9 (± 8.8). Dorsi flexion: pre: 14.0 (± 6.9) post: 15.5 (± 6.1). Ballet technique evaluations on a scale of 1-9: stamina: pre: 4.9 (± 1.1) post: 4.8 (± 1.4). Precision: pre: 4.9 (± 1.3). Post: 4.5 (± 1.3). Performance: pre: 5.0 (± 1.2). Post: 4.7 (± 1.1). Averaged Score: pre: 4.9 (± 1.2) post: 4.7 (± 1.2) *. [1]Values are mean ± 1SD. *The adjusted post-test mean was significantly different from the pre-test mean ($p<0.05$) as determined by analysis of covariance.			
Do increases in selected fitness parameters affect the aesthetic aspects of classical ballet performance?	Randomised Control Trial Performance	Gender: 14 females and 3 males Age: Experimental: 19.0 ± 1.0 Control: 19.0 ± 2.34 Dance Style: Ballet	17 Experimental = 9 control = 8	High-intensity interval training and circuit training Intervention: 10x 1h sessions over 10 weeks during a rehearsal period. 1x sessions p/w. Sessions were led by 2 pros and followed the same programme each time. Aimed at improving aerobic capacity, and muscular endurance using high-intensity interval training (HIIT) and circuit training. Aerobic: alternating 1-min activity with 1-min rest, for 20 minutes. Work effort: 15-18 points /20 on Borg scale (RPE). Circuit: 1-minute training focusing on target muscles, followed by 1-	10-week intervention with one 60-minute session per-week	Changes in score from pre- to post-test intervention: performance: Total performance score: control: 1.56 ± 3.97 experimental: 6.25 ± 4.10*. Coordination: control: 0.3 ± 0.50. experimental: 0.5 ± 0.54. Control of movement: control: 0.2 ± 0.83. experimental: 1.0 ± 0.54*. Spatial awareness: control: 0.1 ± 0.60. experimental: 0.5 ± 0.76. Accuracy of movement: control: 0.6 ± 1.01. experimental: 0.8 ± 0.46. Skill level (virtuosity): control: –0.1 ± 1.36. experimental: 1.1 ± 0.84*.	Fitness training has a positive effect on aesthetic dance performance. Intervention group: overall performance scores ($p = 0.03$)	Future research should use a larger and more varied sample for future research	23

E. A. Twitchett, M. Angioi, Y. Koutedakis and M. Wyon 2011 [68]		Level of Experience: Professional dancers within a touring dance company		minute skipping with a 10-second changeover. Exercises: spine hyperextension, press ups, abdominal curls, elbow extension (Dyna-band), lunges, bicep curls (Dyna-band), bar pull-ups, each followed by skipping. Control did not complete any additional training.		Timing and rhythmical accuracy: control: 0.4 ± 0.8. experimental: 0.5 ± 9.3. Response to phrasing and dynamics: control: 0.1 ± 0.60. experimental: 0.6 ± 0.92. Expression and interpretation: control: 0.2 ± 0.67. experimental: 0.25 ± 0.46. Communication/projection: control: –0.3 ± 0.87. experimental: 0.5 ± 0.76. "X-factor": control: 0.0 ± 0.50. experimental: 0.9 ± 0.99*. *Indicates a significant pre- to post-intervention difference, where p <0.05.			
Effects of partner's improvisational resistance training on dancers' muscular strength R. E. Vetter and S. Dorgo 2009 [80]	Non-randomised Control Trial Strength	Gender: Female Age: Experimental: 20.1 ± 2.3 Control: 21.0 ± 1.9 Dance Style: Not Recorded Level of Experience: College dance students	19 Experimental = 11 control = 8	Partners Improvisational Resistance Training (PIRT) PIRT: completed in 1st half of dance class, consisted of 8 exercises: 1. back extension; person 1: prone position, and lifting the chest off the floor; person 2: resisting person 1's upper back. 2. Abdominal curl; Person 1: supine position and lift shoulders from the floor; Person 2: applied resistance to the shoulders. 3. Biceps curl; person 1: standing with back against the other's front, bending and straightening knees; person 2: in the back raising and lowering the partner. 4. Lat pull; person 1 and 2: facing one another, toes touching, holding each other's wrists with bent elbows. Partners extended their arms pulled the upper arm back and allowed the elbows to flex. 5. Bench press; person 1: lying in a supine position, arms extended toward the ceiling, flexed and extended the elbow; person 2: placed resistance on person 1's palms. 6. Leg press; Person 1: lying in a supine position with flexed hip, feet toward the ceiling then flexed and extended knees pushing Person 2 into the air; Person 2:	8-week intervention period, 3 sessions per week and 60 minutes each session.	Strength (kg): Experimental: Leg extension: pre: 45.7 ± 2.5 post: 55.7 6 ± 3.6. Leg flexion: pre: 39.8 ± 2.4 post: 48.5 ± 2.1. leg press: pre: 163.6 ± 12.8. post: 225.5 ± 11.0. Bench press: pre: 36.6 ± 4.5. post: 45.2 ± 4.8. Lat pulldown: pre: 30.2 ± 1.7. post: 33.6 ± 1.7. Back extension: pre: 82.9 ± 3.6. post: 96.7 ± 2.1. Sit-up: pre: 6.6 ± 2.3. post: 13.0 ± 3.1. Strength (kg): Control: Leg extension: pre: 41.9 ± 4.0 post: 44.9 6 ± 2.3. Leg flexion: pre: 30.9 ± 3.0. post: 40.0 ± 3.3. leg press: pre: 170.5 ± 10.4. post: 188.6 ± 9.1. Bench press: pre: 31.6 ± 4.7. post: 32.9 ± 2.2. Lat pulldown: pre: 23.7 ± 1.3. post: 28.1 ± 1.6. Back extension: pre: 76.5 ± 6.6. post: 83.4 ± 6.0. Sit-up: pre: 8.5 ± 2.2. post: 11.4 ± 3.3.	The PIRT program was effective at improving most in strength but less in body composition. EXP: leg extension ($p<0.0001$), leg flexion ($p<0.0001$), leg press ($p<0.0001$), bench press ($p<0.002$), lat pulldown ($p<0.003$), back extension ($p<0.0001$), and sit-up ($p<0.001$) strength. CON: leg flexion ($p<0.0001$), lat pulldown ($p<0.0008$), and back extension ($p<0.026$) strength. EXP stronger at post-test than CON in all seven 1RM strength	Lower waist and hip circumference	18

				placed resistance on Person 1's feet soles using the pelvic girdle region. 7. Inverted military press; person 1: in a handstand, flexed and extended the elbows; person 2: acted as the spotter and assisted by holding the person's hips, thighs, or feet. 8. Leg curl; person 1: lying in a prone position then flexed and extended the knee joint; person 2: placed resistance against person 1's ankle area using the hands. Each exercise performed 2 sets: 10 reps over 8 weeks. Improvisational partner work was explored after the 8 exercises in the 1st half of the lesson alternating upper and lower-body exercises. Partners were not matched up and were allowed to pair before class. When dancers improved in strength, extra exercises were added such as an advanced push-up, where person 1 gets into a push-up position and person 2 lies on their back.			measures; significant in leg extension ($p<0.023$), leg press ($p<0.004$), and bench press ($p<0.049$)		
Dance, balance and core muscle performance measures are improved following a 9-week core stabilization training program among competitive	Case Report Strength and Performance	Gender: Female Age: 19.7 ± 1.1 Dance Style: Not Recorded Level of Experience: University students who were involved in their dance team	24	Core stability exercise training programme. Intervention: 9-week core stabilization training program using: balance/dance posture, strength, endurance, and proprioceptive control of the core and lower extremity. A step-by-step information video was given to all participants showing exercises in the training programme. The video had timing and number of reps and sets. Sessions = 3x p/w 30mins. 2x with author and 1x on own, cues and feedback given. Protocol: progression of 3 levels with 5-7 exercises per level, focus on sensorimotor control, activation and strengthening of 1) TrA and internal oblique, 2) lumbar multifidus, 3) gluteus medius, quadratus lumborum and external oblique, 4) gastroc-soleus, 5) whole body major muscle groups. Difficulty adapted from another core stabilization program [82]	9 weeks, 3 sessions per week	Strength (kg): RL: pre: 13.75 (± 4.09). Post: 15.13 (± 3.32). LL: pre: 14.24 (± 4.70). Post: 15.72 (± 3.30). Single Leg Heel Raise (repetitions): RL: pre: 37.13 (± 10.05). Post: 37.96 (± 9.97). LL: pre: 36.67 (± 9.54). Post: 37.38 (±8.81). Performance: maximum number of pirouettes turned in front passé relevé with arms in first position (revolutions): utilize ADIM: pre: 2.21 (±0.63) post: 2.55 (± 0.81).	The core stabilization programme improves pirouette ability, balance, and muscle performance. Significant improvements: single leg balance in passe' relevé and bilateral anterior reach (both $p < 0.01$), number of pirouettes ($p = 0.011$), and all measures of strength ($p < 0.05$) except single leg heel raise.	A broader population in future or a narrower one as these participants studied both ballet and jazz	17

collegiate dancers T. Watson, J. Graning, S. McPherson, E. Carter, J. Edwards, I. Melcher, et al. 2017 [81]				. Level 1: stationary static movements to slow movements. Level 2: static contractions in unstable situations to dynamic movements in a relatively stable position. Level 3: dynamic movements in unstable situations. Participants progressed after they completed an exercise level for 3 weeks.					
Whole-body vibration training increases vertical jump height in a dance population M. Wyon, D. Guinan and A. Hawkey 2010 [6]	Randomised Control Trial Strength	Gender: Female Age: Experimental: 19.0 ± 2.3 Control: 21.1 ± 2.0 Dance Style: Not Recorded Level of Experience: Undergraduate dance students in 3rd year	18 Experimental = 9 control = 9	Whole-body vibration training programme Intervention: static-position vibration, 2 sessions p/w for 6-weeks. Rest = 2 days. Held each position twice for 30 secs, frequency = 35 Hz, amplitude = 4 mm. Positions: demi-plié in 1st, right-leg leading lunge with the front foot on the platform, left-leg leading lunge, high toe raise (max plantar flexion), and bent over hamstring hold (legs remained straight, torso bent over from waist more than 90° similar to straight leg deadlift). The control group carried out the same intervention (static holds) but without the vibration.	6-week intervention, 2 sessions per week for 5 minutes	Vertical jump (cm): intervention: pre: 38.8 + 1.94. post: 41.1 + 2.1. control: pre: 36.3 + 6.71. post: 34.8 + 6.21.	WBV training is good for improving jump ability. Vertical jump height increased significantly ($p<0.05$) in the intervention group than in the control group.	Optimum frequency, duration, amplitude levels and long-term effects should be looked into	23
A comparison of strength and stretch interventi	Randomised Control Trial ROM	Gender: Female Age: Strength conditioning :17.0 ± 1.6.	35 Strength training = 11 low-intensity stretch	Strengthening and stretching interventions are split into 3 groups. Strength training = 11 low-intensity stretch = 13 moderate-intensity or high-intensity stretch = 11. 3 groups for six weeks: strength conditioning, low-intensity stretching, and moderate-intensity and high-intensity stretching.	6-week intervention	PROM: strength conditioning group: RL: pre: 132 ± 12.19. Post: 150 ± 11.81†. LL: pre: 128 ± 14.97 Post: 147 ± 11.62†. AROM: RL: pre: 84 ± 13.27. Post: 105 ± 16.28†. LL: pre: 84 ± 17.87. Post: 103 ± 12.92†.	Lower-intensity stretching improves active and passive ROM. PROM no significant difference between	Moderate-intensity stretching should be used alongside strength conditioning.	23

ons on active and passive ranges of movement in dancers: a randomized controlled trial M. A. Wyon, A. Smith and Y. Koutedakis 2013 [51]		Low-intensity stretch: 17.0 ± 2.0. Moderate-intensity or high intensity stretch: 17.0 ± 1.9. Dance Style: Not Recorded Level of Experience: Moderately training college dancers	= 13 moderate-intensity or high-intensity stretch = 11.	Strength: focused on hip flexors, used end-of-range strength by working at the last 10° of AROM. AROM, completed by partners' help. Then leg was lifted as high as possible by the dancer away from the partner, using hip flexor strength and keeping hips horizontal; held for 3 seconds. After 3-secs the partner grabbed the weight of the limb again. Exercises = 3 sets, 5 - 10 reps on each leg. Low-intensity group: lower limb stretching = 5x p/w. Muscles worked: gluteal, hamstring, quadricep, and calf muscles. Held each stretch in an intensity RPE of 3/10 for 1 min, 0 points being no stretch and 10 being an aggressive stretch. Moderate-intensity or high-intensity: normal stretching regimen. Intensity = 8/10 RPE for 1 min using the same muscles as the low-intensity group. Participants were given no additional information on stretches, duration, frequency, or ideal times to stretch.		Low-intensity stretching group: RL pre: 134 ± 12.53. Post: 148 ± 14.66†. LL: pre: 133 ± 17.85. Post: 144 ± 22.50†. AROM: RL: pre: 92 ± 17.25. Post: 112 ± 16.28†. LL: pre: 89 ± 14.63. Post: 105 ± 14.12†. Moderate-intensity or high-intensity stretching group: RL: pre: 132 ± 12.74 141 ± 6.72†. Post: 123 ± 16.50 133 ± 15.97†. AROM: RL: pre: 76 ± 14.92. Post: 88 ± 12.12. LL: pre: 79 ± 12.52. Post: 81 ± 14.52. *Indicates significant differences (P< 0.05). †Indicates significant differences (P< 0.01). ROM, range of movement.	groups: (range increase: 9–200 p<0.01). AROM: ST and low-intensity stretch groups significantly improved ROM (range increase: 20–300) compared to moderate-intensity or high-intensity stretch group (p<0.01).	Look into various genres	

Key: p/w = per-week. 1RM = One repetition maximum. Reps = repetitions.

3.1.4 Data Extraction

The reviewer RJ extracted relevant data from all studies and added this information to Table 2. The study information such as Paper (Title, Author's, Year), Study Design and Category, Participants, Sample Size, Method/ Intervention, Duration, Results, Outcome, Limitations and the score from 'Kmet et al.'s, Quality Assessment Tool' [83] (Table 2) were all extracted. Two reviewers from the team (PD, MW) had checked any information extracted. If any discrepancies occurred another independent reviewer (REH) solved these. If there was any information that was missing or unclear, the reviewer RJ contacted the authors of the original study. This did not occur as the information was clear in each paper.

The data extracted from the dependent variable strength was noted in Table 2 within the method/intervention section of the literature review. The independent variables of ROM/flexibility and performance of each paper have been detailed in Table 2 in the results section of the literature review.

3.1.5 Methodological Quality Assessment

For the first and second screening, all of the included research papers were graded using 'Kmet et al.'s, Quality Assessment Tool' [83] (Appendix 2). The tool is performable on quantitative research studies, all of the studies that will be found will be quantitative research. To assess the methodological quality of research sufficiently across multiple methodologies. The 'Tool' has 14 questions which use a 3-point scoring system. A 'Yes' answer would receive 2 points, a 'Partial' answer would receive 1 point, a 'No' answer would receive 0 points and finally, an 'N/A' answer would also receive 0 points. The scoring ranged from 0-28 with higher scores indicating better quality research. The scores for each paper can be shown in Appendix 3. They were independently graded by the research team (RJ, MW, PD, REH) differences in scores were discussed as a group and a group decision was agreed upon. If further disagreement, then an independent reviewer was used, this was not necessary as scores were all agreed upon. Endnote 20 (Clarivate) and Microsoft Excel 365 were all used to assist in the data extraction and rating process.

One of the reviewers has extensive experience in the scientific field of dance (MW). The other reviewer has a BSc in the field of dance and a Level 3 Personal Training Qualification and is the current writer for the MPhil dissertation (RJ). Before the literature review, 'Kmet et al.'s, Quality Assessment Tool' [83] (Appendix 2) was chosen as the assessment criteria for literature and both reviewers studied 'Kmet et al.'s, Quality Assessment Tool' [83] (Appendix 2) research before assessing the research papers. Within the first assessment, the Cohen's Kappa inter-rater reliability measured a coefficient of 0.58 which was not sufficient for substantial agreement between the reviewers. Criteria were reviewed and discussed again to complete another test. The second assessment, the Cohen's Kappa inter-rater reliability measured a coefficient of 0.81 which indicated substantial agreement between both reviewers. Discussions were then continued if any other differences occurred between scores of other papers. It is important to note, that there may still be subjective bias between answers which may influence the ratings.

3.2 Literature Review Results

At the end of the literature search, 15 research papers met the inclusion criteria [2, 6, 19, 46, 47, 51, 55, 61, 68, 75, 76, 78-81]. All three of the screening reviewers had

agreed on all research papers to be included in the study. The search strategy for the literature review is shown in Figure 1. The research papers were then categorised into RT, ROM and performance depending on what the research was focusing on. There were some overlaps in topical content with some research so the results from each research study may have fit into multiple or all of the categories. Of the research, 13 research studies showed improvements in muscular strength from RT interventions [2, 6, 19, 46, 47, 55, 61, 75, 76, 78-81]; 6 research papers on flexibility or ROM had improved within the participants [2, 19, 47, 51, 55, 75]; improved performance [2, 47, 68, 76, 81] was found within 5 research papers out of the 15. Within Table 2 dance styles were extracted and added to this table within the participant's section. The category of paper was also added to Table 2 showing whether the paper relates to strength, ROM, performance, or all/some of the categories. All collected data from the results can also be found in results Table 2.

3.2.1 Quality of Included Studies

Each of the included research papers was assessed on the quality of methods using 'Kmet et al.'s, Quality Assessment Tool' [83] (Appendix 2). The tool uses 14 questions to score the reliability and risk of bias for quantitative papers. The scores of the current literature review ranged from 14-23 out of 28; the higher the paper scored the better quality the paper was. Please refer to Table 2 for scores of each paper and information. Refer to Appendix 3 for a score breakdown of 'Kmet et al.'s, Quality Assessment Tool' [83].

3.2.2 Participant Characteristics

Between all 15 research studies, there were a total of 327 participants; 289 were female participants, 16 were male participants and in one paper [78], there were 22 participants in which gender was not reported. Of all the tested participants, 221 were tested within an intervention training group and 106 were tested within a control group. Within the research, there were various levels of training within the participants. For example, college students from ages 16 up to age 35 where the skill level was professional, this data can be identified in Table 2. There were multiple dance genres the participants had trained in, if recorded in the research papers as to which genres the participants were a part of, this was added to Table 2. There were 9 research papers which did not report genres [2, 6, 19, 46, 51, 75, 79-81]. More details about the participants and the type of interventions can be found in Table 2.

3.2.3 Outcome Measures

Data extraction found varied methodologies and testing protocols. Between the 15 research papers, all had reported participants' age [2, 6, 19, 46, 47, 51, 55, 61, 68, 75, 76, 78-81]. Further details included height, where 12 research papers had reported [2, 6, 19, 46, 47, 51, 55, 68, 76, 78-81], 13 research papers reported on body mass [2, 6, 19, 46, 47, 51, 55, 61, 68, 76, 78-81], 7 research papers reported on skinfolds [2, 6, 46, 47, 61, 76, 80] and 5 research papers reported on the volume and/or circumference of different areas of the body for example thigh or chest [2, 6, 55, 79, 80].

Muscular strength tests focused on the lower body, the muscles tested were hamstrings [2, 46, 47, 61, 75, 80], quadriceps [6, 19, 46, 55, 61, 76, 78, 80] and calves [2]. There were a few upper body muscle function tests, these were push-up tests [76], and abdominal crunches [75]. There were three research papers which

included 1 Repetition Max (1RM) tests [46, 79, 80], and three research papers used dynamometry tests [47, 61, 81].

Flexibility and ROM tests included developpé a la seconde [2, 51, 55], arabesque [2] and developpé devant (anterior leg flexion) [2]. Out of the research, three used either a standing or supine straight leg raise test [19, 47, 75]; one reported hip ROM [2]. The main muscle tested out of all of the flexibility and ROM research was the hamstrings [19, 47, 51, 55, 75].

Performance was measured within 5 research papers [2, 47, 68, 76, 81]. Tests included scoring tests such as the AC Tool [76] a dance sequence performed to and from a circular shape on the floor until somatic fatigue was marked on technical/artistic competence such as alignment, posture and articulation, participants were deducted points if they were not travelling to and from the circle after each dance phrase [47]. A petite allegro ballet sequence was scored in one paper to test performance. The petite allegro was tested by three judges from 1-9 points on stamina, precision and performance [2]. Another paper used a performance proficiency test which focused on areas such as musicality, precision and skill [68]. The final paper tested pirouettes in the front passé position whilst completing as many consecutive turns as possible before breaking technique, the number of revolutions was recorded [81].

3.2.4 Training Interventions

Training interventions included single-focus, multi-focus and dance-based programmes. The single-focus interventions included Whole-Body Vibration (WBV) training [6, 55, 76, 78], weight training or RT [2, 46, 61, 79], Pilates [75], plyometric training and core stabilisation [81]. Multi-focus interventions included aerobic and circuit training [68], and aerobic and strength training [47]. There was one study which created a Partners Improvisational Resistance Training (PIRT) programme [80]. Amongst the 15 research papers, one used dance training interventions [19]. Six weeks out of the eleven were used to train ballet technique and the remaining five were used to practice contemporary technique [19]. Of the 15 research papers, one used a strength and stretch training programme for different experimental groups within the study [51].

3.2.5 Intervention Outcome Summary

In all of the RT research, either a form of muscular strength, flexibility, ROM and/or performance had improved. Some of the studies had positive effects on aesthetic dance performance, flexibility or ROM which were reported in 9 research papers [2, 19, 46, 47, 61, 75, 76, 80, 81]. Dance performance had been improved in 8 studies using a training programme in an intervention style [2, 47, 61, 68, 75, 76, 78, 81]. Of the 15 research papers, 6 reported flexibility improvements due to intervention [2, 19, 47, 51, 55, 75]. Overall, strength, flexibility/ROM and/or performance were improved within all 15 of the research papers [2, 6, 19, 46, 47, 51, 55, 61, 68, 75, 76, 78-81].

3.2.6 Resistance Training

The 13 studies which looked into improving muscular strength [2, 6, 19, 46, 47, 55, 61, 75, 76, 78-81] all reported improvements. Some of these included an improvement of 32-40% for leg press [46]; 21.9- 23% for leg extension [46]; 21.8-23% for leg flexion [80]; 25% for calf raises [2]; 23.3% for bench press [80]; 11% for latissimus dorsi pulldown [80]; 16.6% for back extension [80]; 98.5% for sit-ups [80];

8.75% for hip adduction and 58.8% for weighted plié/relevé [2]. Other studies reported an 11.4 ± 4.1 kg improvement in knee extensor maximal strength [47], 1.38-1.48kg hip abductor improvement [81] and a 16% increase in hamstrings and quadriceps torque [61]. More results can be found in Table 2.

3.2.7 Flexibility and ROM

Within 6 studies which tested on flexibility/ROM, all had improved [2, 19, 47, 51, 55, 75]. These included an improvement of 13% in hamstring flexibility [75], hip extensor flexibility by 29.95° and 26.18° [19], 14.7 ± 3.6° hamstring flexibility [47], 117.5 ± 7.92° right-leg active ROM (AROM) [55], 123.3 ± 8.6° anterior hip flexibility, 127.1 ± 9.8° lateral hip flexibility [2] and passive ROM (PROM) by 13% and AROM was improved by 23% [51]. More results can be found in Table 2.

3.2.8 Performance

There were 5 research papers [2, 47, 68, 76, 81] which had improved within performance but there was no homogeneity in measuring performance or aesthetic competence between the studies. All studies reported an improvement for the intervention groups; 38 ± 12.92 to 43 ± 6.34 [76]; 73.9 ± 16.2 to 109.2 ± 21.3 points [47]; 4.8 ± 1.8 to 5 ± 1.6 points [2]; and 6.25 ± 4.10 point improvement [68]. One study used pirouette performance and reported an improvement from 2.21 ± 0.63 to 2.55 ± 0.81 revolutions [81]. More results can be viewed in Table 2.

3.3 Literature Review Discussion

The current literature review focused on the benefits of incorporating RT into a dancer's training by collecting data from intervention studies within various dance styles such as contemporary, modern dance and ballet. Dance parameters such as strength, ROM/flexibility and performance were focused on to collect any improvements in data. There were gaps within the collection of data on the style of jazz dance after conducting the systematic literature review. The findings were mostly formed from contemporary, ballet and modern dance styles which incorporated RT intervention programmes in the research.

Another systematic review has been published recently which looks into strength conditioning, flexibility and aesthetic competence [64]. The current literature review differs from the inclusion and exclusion criteria of the recently published systematic review and meta-analysis paper. The 15 research papers in the current study show results of muscular strength, flexibility/ROM and performance within interventional studies. Each study has found improvements in muscular strength, flexibility/ROM and/or performance [2, 6, 19, 46, 47, 51, 55, 61, 68, 75, 76, 78-81]. The results from the interventional studies have been meticulously marked with the ‘Kmet et al.’s, Quality Assessment Tool’ [83] (Appendix 2) and the scores from each paper can be found in Appendix 3. The recently published paper similarly used the same marking tool as the current dissertation [64] but tested on upper and lower body strength, flexibility and aesthetic competence.

3.3.1 Resistance Training

Resistance training, alongside dancers' usual schedules, has been claimed to be beneficial [3]. The research included in this review reinforces that resistance training is beneficial for dancers [2, 6, 19, 46, 47, 51, 55, 61, 68, 75, 76, 78-81] and highlight the benefits of incorporating RT alongside mainly ballet, modern and contemporary dancers with improvements in muscular strength, flexibility/ROM and dance performance [2, 61, 68, 76, 78].

Amongst the analysis of research, there were 13 out of the 15 research papers that had shown improvement in muscular strength [2, 6, 19, 46, 47, 55, 61, 75, 76, 78-81]. There were two studies in which participants had the greatest improvement in strength throughout an intervention process [47, 80]. One of the highest-scored research papers [47] which was 23 on the 'Kmet et al.'s, Quality Assessment Tool' [83]; reported significant increases in the strength training group's maximal knee extensor strength, whilst the control group's strength decreased over the same period. The experimental group also reported increased flexibility and dance performance after the strength training intervention. Another paper [80] used a unique intervention programme by using PIRT to increase strength. This study's score was 18 on the 'Kmet et al.'s, Quality Assessment Tool' [83], the results within muscular strength across several muscle groups were: latissimus dorsi, hamstrings, quadriceps, abdominals, erector spinae, and pectorals.

Dancers in many styles such as ballet, modern, contemporary and jazz have previously been hesitant to incorporate RT such as weight training into their dance schedule due to ideas that dancers will increase muscle size drastically [3]. Dramatic aesthetic changes have not been discovered within the intervention research which incorporates RT alongside dance training [2, 6, 19, 46, 47, 55, 61, 75, 76, 78-81]. The current literature review results help to justify why dancers should incorporate RT into their dance training as well as mould the idea of RT as a positive incorporation into dancer's schedules [2, 6, 19, 46, 47, 51, 55, 61, 68, 75, 76, 78-81]. It can be identified from the research that dancers who train in genres such as ballet, modern and contemporary should incorporate RT into their schedules [2, 3, 6, 19, 46, 47, 51, 55, 61, 68, 75, 76, 78-81]. Incorporating the use of RT can help improve muscular strength, ROM and performance which are crucial for dancers to execute movements with precision [3]. Resistance training can target different muscle groups (such as upper body – latissimus dorsi, biceps and triceps as well as lower body – hamstrings, quadriceps and calves) which are important for dance movements (such as kicks, leaps, pirouettes), allowing dancers to develop the necessary strength and control to perform intricate routines effectively [32, 33]. Additionally, by engaging in RT, dancers can build a solid foundation that supports their overall physical fitness, contributing to improved performance and longevity in their dance careers [1, 3, 17, 79]. Dancers within the genre of jazz specifically still need intervention studies completed on their populations to view if RT is beneficial for them too [3, 4].

After conducting the literature review, there were 14 research papers which conducted RT interventions [2, 6, 46, 47, 51, 55, 61, 68, 75, 76, 78-81] and one research paper which used dancers and non-dancers to complete a contemporary and ballet dance training intervention using plyometric movements [19]. In the context of other relevant literature, the non-dancers within the research strength and flexibility was tested after an 11-week dance intervention and improvements were

found [19]. Although this paper has different participants than other literature, the improvement after the intervention adds to the analysis of strength and flexibility results. Amongst the research, 3 papers used whole-body vibration training (WBVT) as a training programme intervention [6, 55, 78] and another similar paper used WBVT alongside circuit training as an intervention [76]. The use of WBVT identifies that there are many ways in which RT can improve ROM, strength and performance and not one specific training programme needs to be used [6, 55, 76, 78]. One study used plyometrics and weight training as an intervention [46]. Another study used solely weight training as its intervention programme [2] which compared to other research it becomes clear that multiple different RT methods can be used for the improvement of strength, ROM and performance in dance and it would possibly be beneficial for all dancers to incorporate RT into their training schedules, more specifically ballet, contemporary and modern dance.

There were four research papers which used strength training as a specific training intervention or combined with other exercise methods [47, 51, 61, 79]. For example, one research paper used a lower-body strength training programme [61]. An upper-body and lower-body resistance training programme was used in another research paper [79]. One research paper combined aerobic and strength training into an RT programme [47]. From the four research papers which used strength training programmes, the last paper had three programmes consisting of strength training, low-intensity stretching and moderate-intensity or high-intensity stretching programmes [51]. Comparing all four papers [47, 51, 61, 79], strength training has continuously shown improvement for dancers' strength, ROM and performance when looking at Table 2 results, hence why dancers could possibly add strength training into their schedules too. Another research paper used Pilates as a training intervention programme [75] which compared to other literature had tested on a broad age range of 16-21 and had found improvements within strength and ROM showing Pilates is another RT example which could possibly be used on a wider age range of dancers. One research paper used high-intensity interval training (HIIT) and circuit training within its programme [68]. Another research paper used core stability training as an intervention [81]. Finally, one research paper created its training programme based on RT using the body weight of oneself or a partner with the help from said partner, this training programme was called Partners Improvisational Resistance Training (PIRT) [80]. Compared to other literature the PIRT [80] has created a unique training programme that has shown improvements in strength for the experimental group of participants and shows that any RT programme created can possibly improve desired strength improvements among dancers.

All of the training programmes used or made within the research of the current literature review had improved on either strength, flexibility/ROM or performance (Table 2). Incorporating RT into a dancer's routine has been discussed in all of the research found in the current literature review explaining that it is beneficial [2, 6, 19, 46, 47, 51, 55, 61, 68, 75, 76, 78-81]. The incorporation of RT can help improve flexibility by strengthening the muscles surrounding the joints, which in turn, allows for greater ROM [2, 19, 47, 51, 55, 75]. Resistance training also helps dancers build the necessary muscular strength and ROM required to execute movements with accuracy [2, 68]. When muscles are stronger and more conditioned through RT, they can better support and stabilize the joints during movements [2, 6, 19, 46, 47, 55, 61, 75, 76, 78-81]. The combination of improved muscular strength and ROM gained

from the incorporation of RT can help dancers achieve greater control and precision for the movements they perform, ensuring the improvement of overall performance [2, 47, 68, 76, 81]. Stronger muscles developed through RT can support dancers in maintaining proper ROM, alignment and posture leading to improved overall performance quality [2, 47, 68]. Additionally, improved muscular strength and ROM gained from RT can contribute to a more aesthetically pleasing and polished dance technique, elevating the dancer's overall performance and stage presence [2, 47].

Overall, muscular strength is important to improve as a dance parameter because of its benefits for ROM, flexibility and performance in dance styles such as ballet, contemporary, and modern dance. One research study which looked into the effects of plyometric training and traditional weight training on dancer's strength, power, and aesthetic jumping ability scored a 23 on the 'Kmet et al.'s, Quality Assessment Tool' [83]. Within the research, the incorporation of the resistance training programmes contributed to a better performance within the dancer's jump ability, the dancer's strength had improved and therefore this enabled dancers to generate and control force more efficiently within their jumps [46]. The literature review found that the thirteen research papers had indeed improved [2, 6, 19, 46, 47, 55, 61, 75, 76, 78-81] due to these improvements, the objective of the literature review evaluating the improvement of strength using an RT programme can possibly be shown through the current systematic literature review results.

3.3.2 Flexibility and ROM

Resistance training programmes can significantly improve flexibility and therefore ROM which has been found in six papers within the literature review [2, 19, 47, 51, 55, 75]. The participants in the research were training with various RT programs and their muscles had worked against the force in their exercises causing muscle contractions [30]. The causation of contractions within muscles would have caused greater muscle strength and hypertrophy in some exercises. Muscle hypertrophy and strength can contribute to improved joint stability and flexibility, consequently improving ROM [19, 75]. Resistance training also helps in strengthening the tendons and ligaments surrounding the joints [47, 51, 55]. Stronger tendons and ligaments provide better support to the joints, allowing them to move more easily [2, 47]. Improving ROM through RT in dance can be achieved by carefully designing a programme that targets specific muscle groups involved in various dance styles [55]. For example, two research studies used a weight training RT programme for student modern dancers where they improved their flexibility and ROM [47, 51]. A targeted approach can help dancers optimise their ROM and strength, leading to better performance outcomes [2]. The two papers mentioned add insight that strength training can benefit a modern dancer's flexibility and ROM within the existing literature [47, 51].

The six papers found on the topic of ROM and flexibility [2, 19, 47, 51, 55, 75] show they are important parameters for a dancer's improvement as it allows dancers to perform movements with greater ROM [3, 47]. By having a greater ROM, dancers in various genres such as ballet, modern, contemporary, and jazz view ROM as more aesthetically important than within other styles [4, 19, 21, 53, 84]. Dancers who have greater ROM can achieve more intricate and challenging positions, transitions, and extensions, which improves the aesthetic quality of a dancer's performance [3, 4, 47, 53]. For example, one study used tests which measured the anterior flexion of a

dancer's leg, lateral leg flexion within the supine position and posterior leg flexion which is an arabesque movement in the prone position, all of the legs in each position were outwardly rotated [2]. One research paper used a développé en second which is an extension of the leg outward in the frontal plane of the body [55]. Another study did a similar using the same position with a passive and active leg hold [51]. When compared to other relevant literature, these studies' unique contribution is RT programmes can help improve the intricate movements and extensions of various dance styles because of the results of p values within Table 2 for these studies [2]. Overall, ROM plays a key role in enabling dancers to express themselves artistically and perform with precision [2, 47, 61]. With the incorporation of RT into a dancer's usual schedule, ROM can therefore be improved further making simultaneous improvements to the overall performance of a dancer [2, 19, 75].

Amongst ROM there are two ways in which you can improve, active range of motion (AROM) and passive range of motion (PROM) [15]. Active and passive ROM are important for dancers because they directly impact the ability to perform movements effectively [51]. Passive ROM refers to how the joint can be moved with the assistance of an external force such as the dancer, a prop or a partner [15]. Passive ROM is essential for dancers as it allows them to achieve positions and movements that may require a wide ROM [85]. On the other hand, AROM is the degree to which a joint can be moved by the dancer alone using their muscles without any external assistance [51, 55]. Great strength and control are clear when a dancer has established their greatest potential of AROM also showing that the dancer can execute choreography with precision and grace [86, 87]. Resistance training is needed to help improve ROM to ensure the muscles are not only strong but flexible to create the elongated lines within various dance styles such as ballet, modern and contemporary [4, 53, 75]. In the context of literature, two papers, which scored 19 [19] and 23 [51] on the 'Kmet et al.'s, Quality Assessment Tool' [83] reported improved flexibility from a muscular strength training intervention. There is a small connection between the improvement of ROM and strength development which helps advance dancers' artistry and performance [76]. Strength training has shown that if implemented into a dancer's usual schedule, it can improve the flexibility and ROM of a dancer's technique and prepare for future rehearsals or performances [2, 47, 61]. Both AROM and PROM are essential for dancers as they contribute to their ability of movement execution with flexibility, strength and overall performance. Dancers use both AROM and PROM to perform complex movements smoothly, expressively and without compromising their technique [52, 54, 84]. One study tested AROM and PROM and improved mainly within AROM because of the improvement, RT programs can be added to a dancer's schedule [51].

Amongst the research, three papers used a passive straight leg raise test all in the supine position either on a plinth or floor [19, 47, 75]. One of the mentioned papers uses a form of RT (Pilates) as an intervention, the paper shows that Pilates has improved the flexibility of the participants due to the results in Table 2 [75]. Compared to other papers, strength had been improved within this study as well as flexibility, showing the improvement of strength is beneficial for improving dance parameters such as flexibility and ROM. Another paper shows the improvement of strength and flexibility using an aerobic and strength training intervention [47]. The paper also explains that RT programmes should be implemented into dancers'

schedules to help improve dance parameters such as flexibility and ROM. One paper using WBV training improved flexibility [55] showing that muscle contraction should be used to improve the rates of flexibility. A weight training intervention had improved the strength, flexibility and performance of the participants in another paper [2] also explaining that RT such as muscular strength training is best implemented into a dancer's schedule alongside their usual dance training to improve dance parameters. As well as this, AROM and PROM were also improved using a strength and ROM intervention programme in one of the participants groups and a similar conclusion of improvement in both parameters was found [51]. By incorporating RT into a dancer's routine, dancers can experience improved muscle strength and ROM, both of which are crucial for improving a dancer's performance. Due to these improvements found in the studies of flexibility and ROM, the objective of the literature review evaluating the improvement of ROM using an RT programme can possibly be shown through the current systematic literature review results.

3.3.3 Performance

Resistance training not only improves physical fitness such as strength and ROM but improves performance in dance too shown in the five papers on improved performance within dance [2, 47, 68, 76, 81]. Additionally, RT can improve muscular power, allowing dancers to perform explosive movements with greater speed and intensity [33, 46]. Moreover, RT contributes to improved endurance, enabling dancers to sustain their performance quality throughout longer routines and can improve their bodies for more demanding choreography such as acrobatic tricks [68]. After incorporating RT and improving endurance, a dancer will lengthen the time in which they eventually fatigue, and their overall performance will improve [88]. The improvement of ROM can be caused by RT incorporation which is essential for dancers to perform more extensive and fluid movements in their choreography [2, 81]. By strengthening the muscles in various ROM, dancers can improve the overall display of their flexibility on stage, inevitably improving a dance parameter for performance [2].

All of the five studies related to performance testing reported an improvement in dance performance post-intervention for the experimental groups [2, 47, 68, 76, 81]. One obstacle that must be mentioned when testing a dancer's performance is that it is difficult to test all dancers from different styles with the same criteria [64]. Each genre has various technical differences, performance qualities and goals, and most importantly dissimilar movements but some movements take inspiration from all genres [9, 22, 23, 25]. Amongst the performance testing tools, there is not one universal tool that applies to every genre [45, 58, 64]. Most assessments rely mainly on the assessor's judgement and knowledge of the genre being tested [64]. On some panels, such as university competitions, there may be around three different judges from different dance styles asked to assess and score other dance styles they are not familiar with. Trying to design a universally used performance testing tool remains a challenge in the dance field [64]. In the current systematic literature review, five research papers tested performance using various testing tools. One research study used an aesthetic competence tool [45] from a paper which the same researcher made three years prior and used the test on contemporary dancers [76] this paper improved dance performance and the results can be found in Table 2. Another research study created a specialised test where they used two circles to dance to and from to assess technique with modern dance students [47]. A scoring

system from one to nine, two being very low and eight being very high in a performance of a petit allegro with ballet dancers was used in another research study [2]. The unique testing and RT programme of this paper helped improve the participants' overall performance and inevitably the experimental group improved their scores in the post-testing [2]. Therefore, RT helps dancers develop the strength to perform complex dance movements such as leaps, jumps, lifts and turns [2, 81]. The increased strength in the dancers' muscles can help execute the movements listed with more control and precision [68]. A performance proficiency test [66] was used in another research study with ballet dancers which was made by the same researcher two years prior [68]. Due to the proficiency test completing inter-rater reliability between judges, the best score was in a margin of ±1.6 and if the margin was higher the judges explained the reason why they chose higher, this allows the scores to be debated and finalised. The unique tool allowed for interesting results in the improvement of performance using an RT programme [68]. The final paper within the five performance research papers used a dance performance balancing test which looked at the improvement of pirouettes, passé relevé, and a star excursion balance test which allowed the participant to stand on one leg and allow the other limb to move whilst maintaining balance from pre- to post-test on contemporary dancers [81]. There are different tests which are used to test on specific parameters within dance but, creating a universal performance testing tool across various dance styles may be necessary for more consistent evaluation.

One paper which scores 23 on the 'Kmet et al.'s, Quality Assessment Tool' [83] reported a significant improvement in aesthetic competence after an intervention consisting of WBV training, jump ropes, mats and free weights to perform moves such as squats and chest press [76]. This was similar to another paper which also reported improved dance test scores by using an aerobic and strength training intervention which used upper and lower body free weight exercises [47]; this study scored 23 on the 'Kmet et al.'s, Quality Assessment Tool' [83]. The interventions which improved performance include; circuit and vibration training [76], WBV [68], aerobic and strength training [47], strength and stretching intervention [51], weight training [2] and core stability training intervention [81]. Whilst using these testing methods the papers previously mentioned all improved performance; by using an RT programme, performance can be improved within the styles of ballet, contemporary and modern dance.

Improving performance in dancers could mean they have improved various dance parameters such as strength, ROM, technique, aesthetic competence or artistry [3]. Incorporating RT interventions such as strength training for example can improve a dancer's ROM, muscular strength, and overall performance within ballet, modern and contemporary [2, 47, 68, 76, 81]. Strength training in particular strengthens muscles which are focused on in training and helps to manoeuvre limbs with ease which is necessary for dancers during performance and training [89]. Hence why it is important to supplement training programmes for strength and ROM within dancers' usual schedule [2, 47, 51]. Improvement in muscular strength has been shown to help improve ROM when incorporating RT into a dancer's schedule [2, 47, 51, 68, 75]. The studies in this review have incorporated programmes such as circuit training [76], weight training [2], PIRT, strength training [47, 51] and WBV training [68, 76] all improved in dance performance within their respective research.

The science behind the improvement of performance within dancers after incorporating RT programmes, lies behind its ability to improve muscle strength, power, endurance, and ROM all of which are essential components for dancers to excel in their craft [2, 47, 68, 76, 81]. Due to these improvements from the performance studies, the objective of the literature review evaluating the improvement of performance using an RT programme can possibly be shown through the current systematic literature review results.

3.3.4 Practical Implications

After displaying results from the 15 research papers, it is mentioned within these papers that RT interventions such as Pilates [75], WBV [6, 55, 78], circuit training and WBV [76], weight training [2], plyometric and weight training [46], plyometrics and dance intervention [19], aerobic and strength training [47], lower-body strength [61], upper- and lower-body RT [79], high-intensity interval training (HIIT) and circuit training [68], core stability [81], strength training and stretching intensities [51], partner's improvisation resistant training (PIRT) [80], all show improvement in the parameter's strength [2, 6, 19, 46, 47, 55, 61, 75, 76, 78-81], flexibility/ROM [2, 19, 47, 51, 55, 75] and performance [2, 47, 68, 76, 81]. These improvements using the implementation of RT into a dancer's usual schedule show a possibility of improvement in a dancer's flexibility/ROM, strength, and performance.

All participants who engaged in RT in the literature review improved their strength, ROM/flexibility or performance. These improvements contribute to the success of improved maximal strength, joint mobility improvement and better artistry. The success of the papers in the systematic literature review could suggest that the implication of RT programmes is beneficial for dancers. In ROM, there was only one paper which looked into both AROM and PROM together [51]. Compared to other literature, this paper focusing on both AROM and PROM shows a unique insight into how they can improve a contemporary or ballet dancer's overall performance similarly with strength. Both increased ROM and strength are essential for AROM, PROM, and the overall performance of a dancer [51, 90]. The other papers that used lower-body flexibility [75], hip extensor flexibility [19], and anterior-posterior and lateral flexion within the leg as well as planter and dorsi flexion within the ankle [2], PROM with a straight leg raise test [47], AROM développé en second [55] did not look into both AROM and PROM together. The improvement of AROM and PROM are both essential for dancers and could potentially both be improved to enhance performance [52, 54, 84]. Due to the lack of papers testing on both AROM and PROM together with the implementation of an RT programme, more research completed on this topic could possibly show the improvement that RT can have on AROM and PROM on many dancers especially filling the gap of knowledge for jazz dancers.

The studies in this review have shown trends that RT has a positive effect on dance parameters such as strength, flexibility, ROM, and performance [2, 6, 19, 46, 47, 51, 55, 61, 68, 75, 76, 78-81]. Due to the strength, flexibility, and ROM all improving, it could be a result of the RT interventions within each paper. The improvement of performance must be viewed with caution because there is no universal testing system for genres within dance [64]. The literature has found improvements within the experimental groups on dance styles such as modern, contemporary, and ballet [2, 6, 19, 46, 47, 51, 55, 61, 68, 75, 76, 78-81]. There are few jazz dance style

intervention research papers so further research could be carried out into this genre to fill the gap within research.

As previously mentioned, performance testing does not have a universal tool which each dancer and dance style should use [64]. A practical implication which can be taken from the performance papers [2, 47, 68, 76, 81], is that a universal tool should be made to use across multiple styles of dance so that performance can be assessed more fairly.

Finally, the current researcher will be identifying and evaluating whether RT programmes can improve the skill of a young adult female jazz dancer's strength, AROM, PROM, and performance using a six-week strength training intervention.

Chapter 4: A Six-week Resistance Training Intervention Study

The current literature review highlighted the benefits of resistance training within certain styles of dance such as contemporary, modern, and ballet. When analysing previous research, there is a need for more studies on participants who have trained in jazz dance. The current researcher understands there is a gap within the research for the style of jazz dance due to the lack of research studies published. No intervention research studies were found on the style of jazz dance within this current literature review. Especially research investigating how resistance training can positively affect various dance parameters such as ROM, strength, and performance. Ethics was passed by the University of Wolverhampton and Buckinghamshire New University before the current intervention study was completed (Code: 10/21/RJ/UOW).

Considering the gap in research within jazz dance, the current researcher will complete a field test for a six-week resistance training intervention for university jazz dance students in their first, second, or third year of university. The aims and objectives for the intervention study can be found in section 2: Aims and Objectives. The second objective will be investigated in the intervention study. Please refer to section 2: Aims and Objectives for the research hypotheses.

4.1 Intervention Study Methodology

The six-week resistance training intervention had to be repeated on a larger cohort after the original five participants. The testing protocols were carried out in the same way to ensure identical and fair testing. There was an addition of the researcher attending the gym sessions of the new seventeen-participant cohort. When the researcher was not able to attend a participant’s gym session, the participants were asked to complete attendance logbooks for each session. The second cohort was invited to partake from a local dance group which the researcher had been made aware of after the first cohort was attained. The researcher needed to gain a larger cohort so then recruited the seventeen new participants. The original five-participant cohort did not have to complete any more training or repeat any testing.

The current intervention was six weeks long, this timeframe was chosen due to the restraints of a master's degree and completing the testing within the allotted time.

The six-week training programme was also an effective timeframe as results can be seen within an exercise in general from as little as four weeks [96]. The six weeks were chosen as a longer alternative but shorter than an eight-, ten- or twelve-week intervention as there was enough time to see improvement and enough time not to take up the participant's time or take up the time of research and data analysis.

There were three tests used; a dynamometer mid-thigh pull test which looked at the improvement of muscular strength in a pre-post-test setting. There was also a passive and active range of motion with a lower body shoulder hold which was used for ROM testing. The final test was a 30-second dance performance test using the PCEM scoring system [58] which was then assessed by two competent dance judges. The order in which the researcher tested was the performance testing, strength testing and then PROM then AROM testing. The tests were completed in this chronology because after the warm-up it was best to dance rather than completing the warm-up and then straight into the AROM/PROM stretching as stretching is usually done after the muscles are warm to prevent injury [41, 86, 97]. Similarly, the strength test was done after the dance and before the ROM tests when the muscles were still warm and ready to be put under force rather than after elasticating the joints and muscles to possible injury if the strength training was completed after stretching [41].

4.1.1 Participants

During the ethics process a power analysis calculated that 54 participants were needed to be recruited for the study (Effect size = 0.5; power = 0.95; pre and post-tests on 2 groups). The power analysis was calculated using a confidence interval method to find a value within the power analysis range (G*Power 3.1.9.7). Another power analysis was done when completing the second lot of testing and a power analysis of 64 was calculated using the power of 0.80 (confidence level = 80%; margin of error = 8%; and population proportion = 50%). Then a third power analysis was completed: power analysis (effect size 0.25, 2 groups, 2 measurement points) indicated 54 participants were required giving the same amount as the original power analysis. However, there were only 5 female participants recruited for the original study. A second recruitment took place after testing was completed of the 5 original participants and the researcher had gained 25 more female participants. Considering the limited participants compared to the power analysis made, results must be taken with caution. The researcher had advertised at local dance schools and had gained a new cohort of participants from a colleague where they work. The colleague in question runs a dance school for young students (age 5+) to university graduates. The participants were recruited via advertisement and any direct information was made either face-to-face or via email. The current intervention study was advertised at Buckinghamshire New University (n=1) alumni of Buckinghamshire New University, Worcester University, London Studio Centre, Hammond (n=4) and a local dance school (n=17). Advertisement emails were also sent out in the original cohort to other institutions, for example, BOA Alumni as the researcher is an Alumni themselves. There were also emails to Hammond, London Studio Centre, and Worcester University but no emails were received back or were computerised responses back. The inclusion criteria for the participants:

- had to either be attending first, second, or third year of study or have attended a university dance course within three years from when the testing took place. The universities in which students studied included: Buckinghamshire New University, Worcester University, London Studio Centre, Hammond, De Montfort University and Performers College.
- All participants were either still teaching or training within the dance industry.
- Participants were recruited if they were currently or previously studying jazz dance at or before any of the institutions listed.
- Participants needed to have at least 3 years of jazz dance experience.
- Preferably needed to have a gym membership to be able to participate in the six-week resistance training programme.

Participants were excluded if they were:

- Injured
- Could not participate in the six-week training intervention.
- Did not participate in any jazz dance training before testing.
- Could not complete both the consent and Par-Q forms.

During the original test, the researcher had to open the search up to recent graduates as the researcher did not gain enough participants from current students. The same criterion was used for the current search for participants, as well as the added inclusion of recent graduates. After the original 5 participants were tested, the researcher changed the criteria from needing a membership at a gym to not needing one so the researcher could then adapt any movements for participants without a membership. However, all participants did have a membership to a gym. The researcher had attended most of the gym sessions of the participants, but logbooks were kept by participants to track the attendance of sessions that the researcher inevitably missed due to work clashes. Participants were excluded if they were injured, and 2 participants were excluded because of this reason. There were 6 more participants who were not included in the study because they had prior arrangements so would not be able to finish or missed a large portion of the testing. Again, results must be taken with caution due to the small cohort.

The age and skill level of participants were university of vocational level dancers within three years of leaving their institution. If they left education, they were still practising or working within the style of jazz dance. The age range of recruitment was 18-24 which is associated with young adults [98]. The skill level of the participants ranged from university students and pre-professionals. The original idea was to have students only, but the researcher was having difficulty with recruitment so opened up the search to pre-professionals. The age range and skill level were used as the researcher had tested on a similar age range of university students within the third year of university for their bachelor's degree and found the age range interesting to test on as they were near their full potential as a dancer. The participants would have understood technique and performance.

4.1.2 Procedures

The participants were given the information sheet and a leaflet advertising the research at the early stages of recruitment. A consent form and Physical Activity Readiness Questionnaire (PAR-Q) were then sent to participants who were taking

part for them to read and send back. All 22 female jazz dance participants had completed these forms. The participants in the experimental group were all given two resistance training programmes which they were to follow during the six-week intervention. Participants carried out the pre-and post-tests before and after the six-week resistance training programme. The tests included a dance performance test (section 4.1.3), a mid-thigh pull dynamometer test (section 4.1.4), and both a passive and active ROM test of the lower body completing a shoulder hold, the description of this test is in section 4.1.4. Please refer to Appendix 4 for the flowchart which breaks down the steps of advertisement, recruitment, testing and data analysis for the current intervention study.

4.1.3 Dance Performance Test

A 30-second dance video containing a short jazz dance to an upbeat pop mix was given to the participants. The movements included strut walks, shoulder rolls, hip and head isolations, double pirouettes, a hitch kick, a posé turn, a split leap, a développé kick, a knee drop, and floorwork, most of which (such as isolations, turns, kicks, leaps) are frequent movements used or taught in jazz dance [22, 23]. Facial expressions were also welcomed and the dance was fast-paced similar to many jazz dance routines today [22]. The participants were given a recording of the 30-second dance performance test a week before testing so they could learn the movements. They then had to complete the dance during the performance test. The dance sequence was carried out in a dance studio and recorded using two cameras, one on the left and right of the room if looking at a landscape map of the given rooms. The recording was sent to two jazz dance judges who both have more than 7 years of training in dance and jazz dance, a bachelor's degree in dance as well as 2 years or more of experience in dance teaching and marking. They both examined the performance of each participant following the PCEM scoring system [58] (Appendix 5, 5.1, 5.2, 5.3).

The PCEM scoring system [58] (Appendix 5, 5.1, 5.2, 5.3) was used for marking the performance of each dance instead of another tool because there were more detailed definitions for the judges to understand what scores should be given out. For example, the Aesthetic Competence tool [45] was not used for the current dissertation as the terms within the marking criteria were much broader and did not have detailed definitions whereas, the PCEM scoring system [58] had descriptive definitions that were easier to follow. The PCEM scoring system [58] even had levels 1, 2, and 3 within each category with its definitions. The Aesthetic Competence tool [45] for example, had: 'Control of movements: definition - Controlled landing from jump/turn, controlled lifting/lowering of limbs, controlled shifting of body weight, core strength, alignment, posture' [45] as a question to score from. Also within the Aesthetic Competence tool [45], overall performance was a part of scoring. The definition of this was 'Does the performance overall impress markers?' [45] and points 9-10 say the words 'Impressive!'. The researcher believed the Aesthetic Competence tool [45] was not as suitable as some judges may interpret impressive as a 9 but some a 10 meaning the difference of a whole point. The researcher believed there could have been more biases between judges on their understanding of what impressive may be to them. Hence why the Aesthetic Competence tool [45] was not used.

Contrastingly, the PCEM scoring system [58] had levels and definitions for performance parameters: ‘Level I: In isolated limb gestures, little or no central body energy or core support underlying the action. Level II: In isolated limb gestures, occasional but inconsistent central body energy or core support underlying the action. Level III: In isolated limb gestures, consistent central body energy or core support underlying the action’ [58]. Having the three-level descriptions of where the participants may be was more specific to the current researcher. The inter-rater reliability from both was similar; the PCEM scoring system [58] was 0.93 to 0.99 and the Aesthetic Competence tool [45] was 0.89 to 0.97. Both were reliable marking criteria but the researcher decided on the PCEM scoring system [58] due to the defined parameters within, making it easier for judges to understand.

In the PCEM scoring system [58] there are Baseline marks from 0, 7, and 14 used to determine what professional level the dancers were at. The current researcher was not looking to determine this as a factor so total scores for marking were used within the results instead. The instructions for how to mark the participants' total scores can be viewed in Appendix 5.3 with the Baseline scores. Before the judges started scoring, there was an initial training session on how to use the PCEM scoring system [58], and any marks that were not similar were discussed between the judges. Using the PCEM scoring system [58] the two judges compared scores from selected videos. Once they had scored a few selected videos, inter-rater reliability was tested on the scores to ensure the judges were marking similarly. After using Cohen’s Kappa inter-rater reliability measured a coefficient of 0.82 which was sufficient for substantial agreement between the judges. It is important to note, that there may still be subjective bias between answers which may influence the scores between judges. Once the judges were given the videos and they had marked each one, the two judges' scores were added together in the results tables for each participant and a total score was given from the sum of both judges’ overall scores.

4.1.4 Muscle Testing

In the current systematic literature review, there were three studies which carried out tests using dynamometer tests [47, 61, 81]. In Table 2 the positive results of the use of the dynamometer tests on dancers show that these are effective, considering the participants were not jazz dancers within the literature review, the test results must be taken with caution. In the current intervention study, the strength tests consisted of a mid-thigh pull test using a digital Takei 5402 Back and Leg Dynamometer. All the equipment apart from the cameras were all the same. The dynamometer mid-thigh pull strength test was straightforward, the participant stood on the equipment in a position very similar to a deadlift and was instructed by the current researcher who is Level 3 trained in personal training to do so. The chain was linked up to the participants' position and then pulled as hard as possible. This score was marked down from pre- to post-test for each participant. The participants had 3 attempts at both pre- and post-test and the best of three was taken for each participant. The difference was also found from pre- to post-test to view whether and how much they had improved.

As previously mentioned in section 1.2, maximal strength is used within this current intervention instead of strength endurance, explosive strength, or speed strength because most studies within the literature review have tested on maximal strength (Table 2). Most of the dance styles tested were modern dance, contemporary dance,

and ballet. Jazz dance requires maximal strength within its movements [22, 99] so the previously mentioned gap in research on jazz dance can be improved with intervention studies. The importance of strength training for professional dancers is essential for performance and technique improvement such as ROM [47, 100]. Interestingly in one literature paper, it was suggested that professional jazz dancers can train with more intricate training programmes to develop their skills within strength, ROM and performance [4]. For amateur dancers, the same study explained that the training of strength and ROM/flexibility should be worked on to keep up with the demands of the physical qualities such as strength and ROM/flexibility within the dance style [4]. The study must be taken with caution however because they did not have a control group and the study only had n=8 participants. More studies should be carried out using an experimental and control group with more participants to understand whether strength, ROM and performance can be positively affected by RT programmes for jazz dancers.

In the current systematic literature review, there were three studies which tested standing or supine straight leg raise tests [19, 47, 75]. The studies in question did not test the style of jazz dance but did improve in the experimental groups in their testing. Due to the fact they did not test on jazz dancers, the same improvement may not happen within jazz dancers as they have different choreographic movements to the genres tested on within the papers so the results should be taken with caution. In the current intervention study, the ROM tests were recorded using two video cameras. Both cameras videoed each participant on the sagittal plane. One video collected the front of the participant's body, and one collected the back of the participant’s body. Data was collected by using an application to get the measurements of each participant. The measurements collected were the obtuse angle of the hip joint measuring from each participant's ankle to the other ankle. The flexibility tests were a shoulder hold using passive and active flexibility. The participants were asked to stand in first position with the feet, and then to shoulder the leg, meaning they would extend their leg by abduction on the frontal plane out to the side. They will do this by maintaining a straight back and leg and holding good posture. For the passive ROM test, they used their hand to hold their foot/ankle or calf muscle and pull the leg slightly towards the body to help increase the angle of ROM. For active ROM, they did not have the assistance of their hand, instead, their leg muscles such as the agonist quadriceps activated and tried to increase ROM by contracting the muscle and lifting the leg higher. The AROM and PROM test was used as other research within the systematic literature review used a similar test to this; the standing or supine straight leg raise test [19, 47, 75]. In this current study, the passive test allowed participants to hold their leg assisted with their hand and the active test did not allow this assistance, the muscle had to work to lift the leg. Like the strength tests the ROM tests were the best of three.

4.1.5 Training Interventions

The six-week intervention process used a two-session week split gym programme for the participants, meaning they carried out one of the two separate gym programmes on alternating weeks throughout the six weeks. The six-week strength training programme consisted of a warm-up, main exercises, and cool-down. The warm-up used cardio, mobilisation exercises, and dynamic stretches. The main strength training exercises had squats, stiff-legged deadlifts, leg press, and calf raises on a box in week one. For week two, there were conventional deadlifts,

walking lunges, glute bridges, and leg raises on a bench. The cool-down consisted of foam rolling all over the body focusing on the legs and using static stretches. The participants were asked to resume their normal routines of flexibility practice if they had any. If not, some stretching exercises would suffice within the gym programme.

As well as this, the six-week RT programme was made by the researcher who has a Level 3 personal trainer qualification and was checked by the research team to ensure it relates to the aims and objectives of the current dissertation. The researcher has 5 years of experience in personal training and has worked with dancers and a few bodybuilders in their duration of work. The warm-up and cool-down are essential for all gym programmes [41, 97] therefore the current gym programme uses a warm-up and cool-down for each session. Foam rolling in the cool-down was also chosen for its prevention of muscle fatigue [101-103]. The exercises used within the gym programme were rationalised before use. The training programme mainly consists of resistance training for the hamstrings. The repetitions and sets were kept the same, but the weight varied from each participant as their muscular strength would not have been the same. The repetitions were usually around 6 and every exercise had 4 sets. There were only 2 exercises that differed from the 6 repetitions. In the first week, calf raises were 10-14 repetitions as these were body-weight exercises. In the second week, the walking lunges were set at 6-10 repetitions to consider balance differences when walking and strength differences in the participants. The repetitions and sets followed the repetition maximum continuum [30] for strength training.

Muscular strength training was used as the main part of the training programme and tests instead of endurance because of the focus within the literature review on whether resistance training programmes had improved a dancer's muscular strength. Muscular strength was important to expand on within research and it was also an interest for the researcher due to them having an interest in their personal training qualification and finding strength training empowering as well as the interest of how strength training improves a dancer's ROM and performance. Moreover, the exercises used within the gym programme focused on knee flexion and hip extension to target the hamstrings. Targeting the hamstrings was important as the tests for strength and ROM both focus on the hamstring muscles. The performance dance also had some hamstring-focused kicks and leaps to show differences from the pre-test to the post-test. Deadlifts were the main exercises used within both weeks of the programme and conventional and stiff-legged deadlifts were used. The deadlift variations were used because they target the hamstring muscles as one of the main muscles within these movements. The stiff-legged deadlift activated the semimembranosus, semitendinosus, and the long head of the biceps femoris [104]. A conventional deadlift has similar muscle activations to a stiff-legged deadlift as it activates the biceps femoris [105]. Other exercises were added such as lunges and glute bridges to activate other muscles within the legs and body to ensure muscular imbalances were not caused [106]. Please refer to Appendix 6 and 6.1 for the six-week intervention programmes used by the experimental group.

4.1.6 Data Collection

There were three tests included in the pre-and post-test. The strength test was a dynamometer mid-thigh pull test, the ROM test was an active and passive shoulder hold test, and the performance test was a 30-second dance motif that the

participants had to learn and perform. The performance test was then marked by two dance judges using the PCEM scoring system [58]. The videos were randomised so the judges were blinded to the pre- and post-test videos of the participants. The groups of participants were randomised. There were 12 participants in the experiment and 10 in the control. The tests were performed in the same order to ensure the same routine for testing was continued with all participants. The first test that was performed on the testing days was the performance test, then it was the PROM test, then the AROM test, and then finally the muscular strength test. All the tests were performed on the same day and took about 1 to 1 hour and a half for each participant.

There were different dates on which the testing took place as the first 5 were completed at least 6 months before the second lot as there had to be a bigger intake of participants advertised for. There was enough data collected in the original cohort, so a second cohort of data was collected. The second intake of participants completed the tests the same way as the original cohort to ensure a fair test. The second cohort was taped within the same week for the pre-test and then the same week six weeks later to ensure there was enough time for testing. Some participants had to also, on the day, go into groups to make the videography quicker but the researcher ensured that the participants were in the same groups from pre-test to post-test so that the judges could mark videos with ease. There were also five different dance studios where the tests took place due to location difficulties. Ten participants had a different dance studio from pre- to post-test, but all locations were dance spaces and used frequently as one. These participants only had different dance studios because of booking ability at the venues. All participants were in the same venue from pre- to post-test but just possibly in another dance studio in the venue. The rest of the participants used the same dance studio location from pre- to post-test as the researcher was able to book the same studio rooms used for the other participants.

4.1.7 Data and Statistical Analysis

Statistical analysis was calculated by using a multivariate analysis of variance (MANOVA) to interpret the differences between pre-test and post-test data. The independent variable (strength) and the two dependent variables (ROM and performance) data were input into Python 3.12 (64-bit) to interpret the pre-and post-test data to then allow the researcher to analyse the results and form whether the research hypothesis was null or alternative. The data was interpreted within the discussion on whether RT programmes had a significantly positive effect on PROM, AROM and performance in young adult female jazz dancers. The data for the MANOVA can be viewed in Table 8.

Tables and graphs are used within the analysis of data to display results. Four graphs show the results from the strength, PROM, AROM, and performance tests and four tables show the same data. The strength graphs show the differences in weight in kilograms that were lifted on the mid-thigh pull dynamometer test from pre- to post-test. The PROM and AROM graphs show the differences in degrees from the pre-and post-test in both the right and left legs. The performance graphs show the PCEM scores [58]. There is one final table that shows the MANOVA results from all the strength, PROM, AROM, and performance data to form the findings from the two hypotheses.

4.2 Intervention Study Results

4.2.1 Participants Information

Table 3: Participants Basic Information

	Intervention Group (n=12)	Control Group (n=10)
	M Value and Standard Deviation (SD)	M Value and Standard Deviation (SD)
Age (Years)	21.5 ± 1.55	20.8 ± 1.23
Height (cm)	166.32 ± 3.93	166.31 ± 4.46
Weight (kg)	57.31 ± 3.88	60.25 ± 8.49

Seventeen participants were in the second cohort of testing which meant they could be added to the data of the original 5 collected previously. In total, there were 22 female jazz dance participants in this study. Twenty-two participants in total still do not meet the effect size of 54 participants or the second re-run of 64 participants but, 22 is a substantial amount more than the original 5 participant cohort. Again, results must be taken with caution due to the small cohort.

4.2.2 Strength

The experimental group all improved within the muscular strength mid-thigh pull dynamometer test from pre-test to post-test. The experimental group improved with a mean and standard deviation (SD) of 8.35 ± 4.05 from pre- to post-test. The control group had a mean and SD of 0.47 ± 1.94 (Table 4) which was only slightly improved within 6 out of the 10 participants, the other 4 did not perform as well in their post-test to pre-test (Figure 2). The t-statistic is t = 7.76, the degree of freedom for the independent t-test is df = 9.64 (10 d.p) and the P value is p = 0.0001 (Table 8).

Table 4: Pre- and post-strength tests of the participants. The table shows the difference in kg from pre-test strength test results to post-test strength results.

	Experimental (n=12)	Control (n=10)
	M Value ± Standard Deviation (SD)	M Value ± Standard Deviation (SD)
Pre-Test (kg)	59.75 ± 18.73	61.3 ± 11.05
Post-test (kg)	77.13 ± 13.33	61.78 ± 9.94
Difference (kg)	8.35 ± 4.05	0.47 ± 1.94

4.2.3 ROM

As shown in Table 5 and Figure 3 for PROM and Table 6 and Figure 4 for AROM all the experimental group participants have improved their ROM. The experimental group had an M value and SD of RL: 13.25° ± 6.35°; LL: 11.67° ± 4.65° for PROM (Table 5). The control group have either slightly improved, but the majority have decreased their PROM (Figure 3) with an M value and SD of RL: -5.9° ± 6.1°; LL: 5.15° ± -5° (Table 5). For AROM, the experimental group achieved an M value and SD of RL: 13.7° ± 6.04°; LL: 12.33° ± 6.39° (Table 6). The control group had an M value and SD of RL: -3.8° ± 4.18°; LL: -4.2° ± 3.05° for their AROM (Table 6). Figure 4 shows all the AROM participant results. The t-statistic for PROM is t = 6.57 and the degree of freedom for the t-test is df = 19.6 (20 d.p). The t-statistic for AROM is t = 6.72 and the degree of freedom for the t-test is df = 19.83 (20 d.p). The P values for both PROM and AROM are p = 0.0001 (Table 8).

Table 5: Pre- and post-passive ROM data (degrees) for right- and left-legs.

	Experimental (n=12)	Control (n=10)
	M Value and Standard Deviation (SD)	M Value and Standard Deviation (SD)
Right-leg Pre-test (°)	95.67 ± 15.31	104.6 ± 7.81
Right-leg Post-test (°)	121.67 ± 17.44	108.6 ± 6.47
Difference (°)	13.25 ± 6.35	-5.9 ± 6.1
Left-leg Pre-test (°)	105.42 ± 15.37	117.1 ± 8.6
Left-leg Post-test (°)	119.42 ± 19.1	102.5 ± 7.21
Difference (°)	11.67 ± 4.65	-5 ± 5.17

Table 6: Pre- and post-active flexibility data (degrees) for right- and left-legs

	Experimental (n=12)	Control (n=10)
	M Value and Standard Deviation (SD)	M Value and Standard Deviation (SD)
Right-leg Pre-test (°)	93 ± 7.92	103.9 ± 11.15
Right-leg Post-test (°)	98.5 ± 7.88	102 ± 11.96
Difference (°)	13.7 ± 6.04	-3.8 ± 4.18
Left-leg Pre-test (°)	86.83 ± 10.79	93 ± 12.33
Left-leg Post-test (°)	104.5 ± 12.38	90.9 ± 8.63
Difference (°)	12.33 ± 6.39	-4.2 ± 3.05

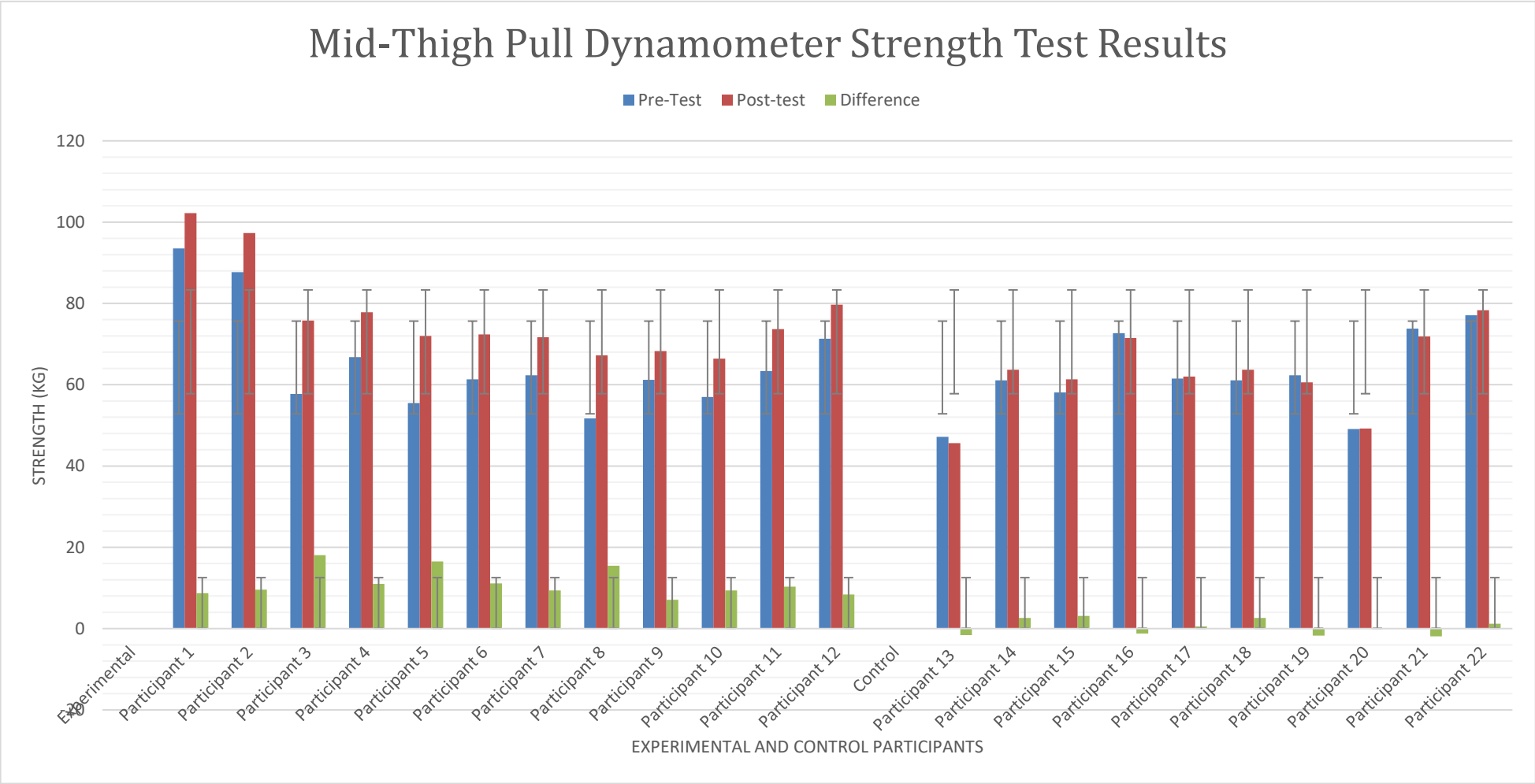


Figure 2: dynamometer mid-thigh pull test strength test results – measured in kg to 1.d.p

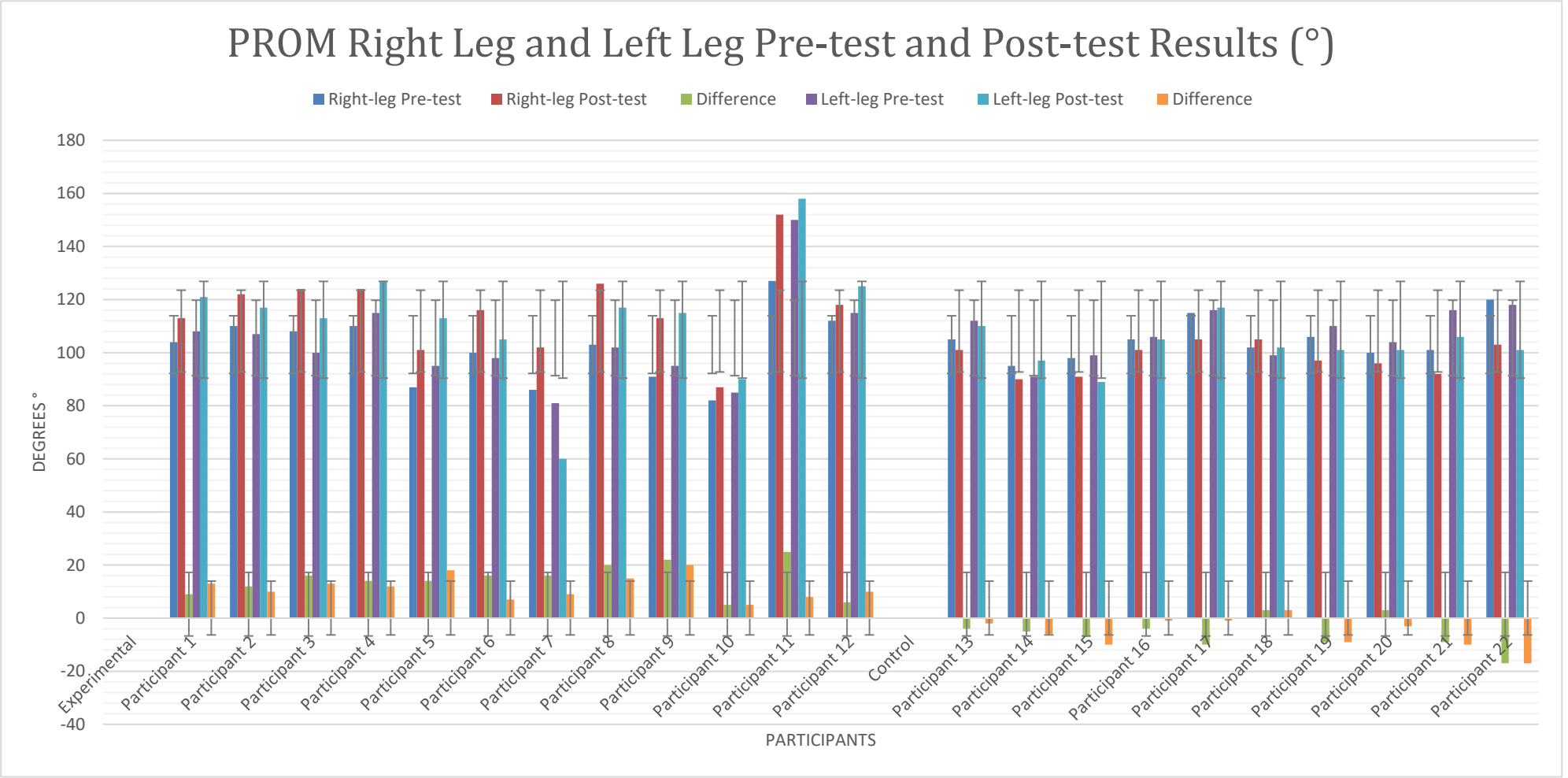


Figure 3: intervention PROM flexibility test results – measured in degrees.

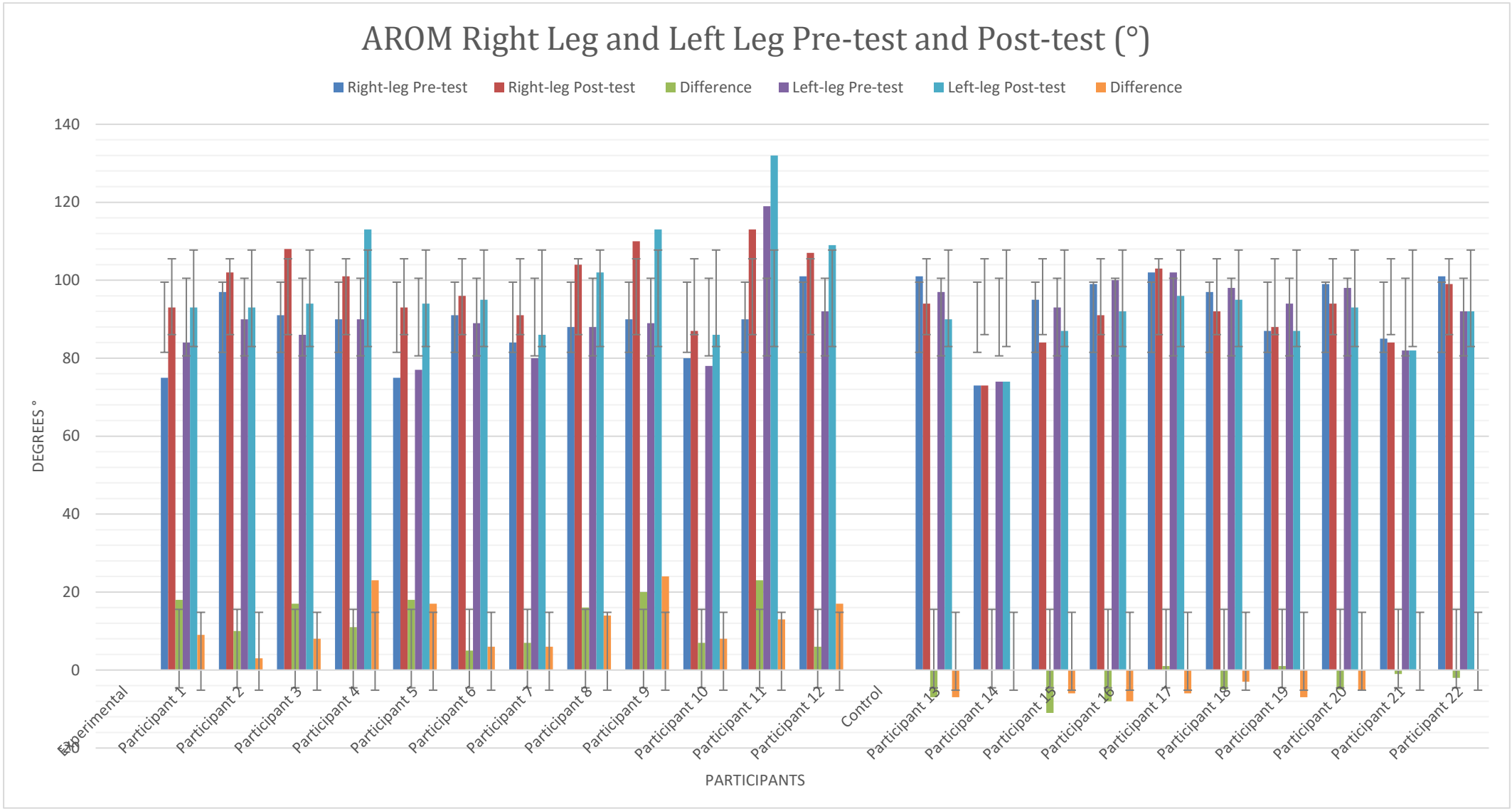


Figure 4: intervention AROM flexibility test results – measured in degrees.

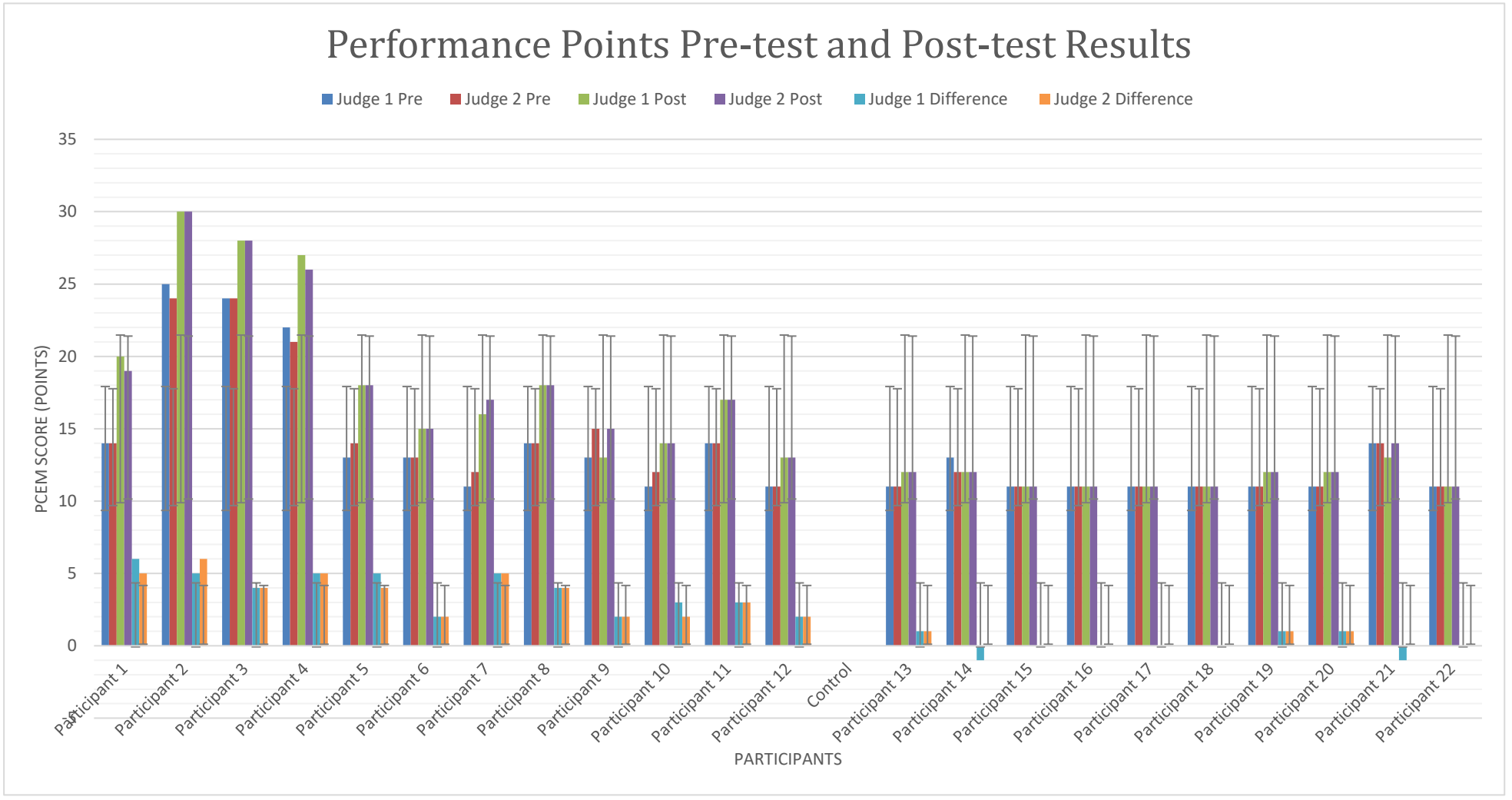


Figure 5: intervention overall PCEM test results

4.2.4 Performance

Figure 5 shows the separate scores from both judges for each participant. Both results from each judge were added together to make a total score for each participant. The PCEM score results in the experimental group improved from pre-test to post-test with both judges, the control group mostly stayed the same. The experimental group scored a SD difference from the pre-test to the post-test of 7.33 points ± 2.58 points. The control group scored a SD difference from the pre-test to the post-test of 0.4 points ± 0.968 points (Table 7 and Figure 5). The t-statistic from both judges is t = 2.22 the degree of freedom is df = 13.17 (12 d.p) for the t-test and the P value is p = 0.0001 (Table 8).

Table 7: PCEM performance test results – this table shows the scores from the pre-test to post-test of both judges overall scores of the participants. It also shows the difference between pre-and post-test overall scores.

	Experimental (n=12)	Control (n=10)
	M Value and Standard Deviation (SD)	M Value and Standard Deviation (SD)
Overall rating pre-test (points)	30.33 ± 7.77	22.1 ± 1.54
Overall rating post-test (points)	32.67 ± 9.15	25.7 ± 2.71
Difference (points)	7.33 ± 2.58	0.4 ± 0.968

Table 8: The effect resistance training has on ROM and performance among young adult female jazz dancers. MANOVA results with F value.

Averages	Value	Num DF	Den DF	F Value	P Value
Wilks' Lambda – Strength	0.305	2	16	18.2326	0.0001
Pillai's trace - PROM	0.695	2	16	18.2326	0.0001
Hotelling-Lawley trace - AROM	2.2791	2	16	18.2326	0.0001
Roy's greatest root – Performance	2.2791	2	16	18.2326	0.0001

4.3 Intervention Study Discussion

The first objective of the intervention study was to identify and evaluate strength, ROM and performance using a six-week pre- and post-testing RT intervention programme on a small young adult female jazz dance population. The second objective is to identify and evaluate the effect of an RT intervention programme on strength, ROM and performance using a young adult female jazz dance population. The rejected hypothesis in the current dissertation is:

Null Hypothesis (H0) – Resistance training has no significant effect on the passive and active range of motion and performance in young adult female jazz dancers.

The accepted hypothesis in the current dissertation is:

Alternative Hypothesis (H1) – Resistance training has a significant positive effect on the passive and active range of motion and performance in young adult female jazz dancers.

After viewing the results in Table 8, the significance of P Value to F Value (when the data of strength training had been used as an independent variable and ROM and performance as dependent variables), shows that the specific RT programme, like the particular strength programme used in this dissertation, has a positive effect on the PROM, AROM and performance in young adult female jazz dancers. When viewing Table 8, the table shows P values all as 0.0001, which is significantly positive. The current dissertation has an alternative hypothesis of H1 due to the findings found in Table 8.

4.3.1 Muscular Strength

As previously mentioned in the introduction (Section 1.2 Resistance Training within Dance), RT programmes like strength training are universally used to improve health and skills within various sports [3, 32]. Ballet teachers incorporated the improvement that RT has into dancers' training due to the scientific research within dance showing positive results on various dance parameters such as jump height, power, strength, ROM, performance and many other skills [2, 6, 19, 46, 47, 51, 55, 61, 68, 75, 76, 78-81] not linked to the aims and objectives in the current literature review and intervention study.

The current intervention study results of the mean and SD suggest that the strength training programme used was beneficial to the young adult female jazz dance population within the current study as all the participants in the experimental group compared to the control group had improved within the mid-thigh pull dynamometer test. Three participants in the control group decreased their strength score from the pre-test to the post-test suggesting that an RT programme like the strength training programme used in this current dissertation can be beneficial in improving a dancer's muscular strength in a six-week intervention period. The RT programme in this current dissertation and the improved results from the experimental group’s strengths scores suggest that the programme was well designed as improved strength was an outcome that was found in various other dance styles [2, 6, 19, 46, 47, 55, 61, 75, 76, 78-81]. It should be noted that, the frequency within the main exercises of the current intervention studies gym programme (Appendix 6 and

Appendix 6.1) has different frequencies for two of the main exercises. For example, in week one, calf raises on a box use the participants' body weight for ten to fourteen repetitions (Appendix 6) and in week two, walking lunges have six to ten repetitions (Appendix 6.1) which variates frequency for each participant. The difference in frequency is an important covariant to mention as some participants may have done more or less than other participants each week, this may have made them improve more or less than others. In future research, this can be controlled by ensuring more clarity on repetitions. Including the data from the literature review, there were 13 other studies which improved within the strength tests used in those papers [2, 6, 19, 46, 47, 55, 61, 75, 76, 78-81]. Some of the tests that improved from the literature review research papers are; the 10 Rep Max (RM) test which was calculated to be a 1RM test [79], a 1RM test [46, 80], an assisted RT strength test [19], dynamometer leg press [78], dynamometer chair test [47, 61], jump height tests [2, 6, 46, 55, 76]. Some covariates should be taken into consideration in the results, as prior RT experience could impact how participants respond to the intervention so, future research studies could complete a questionnaire to honour this covariant.

Comparing the literature review research papers to the current research, the current participants within this dissertation had the highest difference from pre-to post-test being 18.1kg (Figure 2), this is more than the 11.4 ($\pm$ 4.1) kg improvement in knee extensor maximal strength within one study using an aerobic and strength training intervention [47]. The experimental groups' overall difference mean and SD are 8.35 ± 4.05 more than 1.38-1.48kg hip abductor improvement [81] from another study that used a core stability intervention using strength exercises such as single-leg heel raises and hip abductors. The higher improvement of strength within the current study may suggest the gym programme created which used movements such as conventional deadlifts, stiff-legged deadlifts, squats, lunges, and glute bridges may be more beneficial to improve muscular strength compared to other programmes in previous research (Appendix 6 and Appendix 6.1). The experimental group participants in this current intervention process had improved with a higher difference in strength than the two previous papers mentioned [47, 81]. The strength results from the current dissertation alongside previous research indicate that the incorporation of an effective RT programme can improve parameters such as muscular strength within different dance genres such as the jazz dancers tested in the current study as well as modern, ballet and contemporary dancers all used in previous research. Reviewing the strength research in the current intervention study, the second objective (Section 2 Aims and Objectives) focussed on the skill improvement of strength using a six-week pre- and post-testing RT intervention programme on a small young adult female jazz dance population.

4.3.2 ROM

Within the introduction (Section 1.3 The Importance of Passive and Active Range of Motion within Dance Training), passive and active ROM was indicated as both important to dance but also everyday movement and sports [50]. Both AROM and PROM are important for dancers because most styles such as ballet, contemporary, jazz and modern dance have a high demand for dancers to have great PROM and AROM for aesthetic performance as the lines of the body will look more elongated to the audience if ROM is greater within these styles of dance [52]. It is important to note another covariant on the experience of the jazz dancers within the study. There

were two training levels which were university students and pre-professionals. The difference in training levels could be a covariate in this current study as pre-professional jazz dancers with more experience may have different starting levels of strength, ROM and performance compared to the university students [4]. The literature review within the current dissertation found improvement in the flexibility or ROM of dancers within 6 studies [2, 19, 47, 51, 55, 75]. The results of the current intervention study can be found in Table 5 and Figure 3 for PROM, Table 6 and Figure 4 for AROM and have similar results.

The results for PROM suggest that those in the experimental group have improved after using a six-week strength training intervention programme. The second cohort of participants was given the task of writing logbooks if the researcher could not attend the training sessions with the participants. Hence, the researcher is confident that the cohort has attended all the strength training sessions. The improvement of PROM in the experimental group suggests that the participants had completed the training programme each week to the best of their ability, the researcher ensured the participants were completing the programmes whether the researcher was present in the training sessions or when asking for a logbook to be completed for sessions that the researcher or participant could not attend. Another covariant should be mentioned about the participants' psychological motivation, each participant's motivation, pain tolerance and mental focus are different from one another's which could influence the outcome of results. The completion of one training session a week is a possible benefit as participants with less knowledge or practice with RT may not find one session of RT training a week. As mentioned earlier, all participants have a gym membership but the frequency of use and what training they already complete within the gym was not questioned. For future research, the frequency of gym training could be asked of participants. Due to the thorough completion of the training programmes by the participants, their PROM improved which may have been due to the strict completion of the intervention. The thorough completion of an intervention is important in the overall improvement of the parameter needing to be improved [107] for example, strength improving PROM. After reviewing the data in Table 5 and Figure 3, the researcher understood that the right legs and left legs of the experimental group had all improved within their PROM. The right legs had improved from the pre-test to the post-test with a mean difference of 13.25° ± 6.35° and their left legs as a group had improved from the pre-test to the post-test with a mean difference of 11.67° ± 4.65° (Table 5). Compared to the control group their right legs had improved from the pre-test to the post-test with a mean difference of -5.9° ± 6.1°, so they decreased the improvement of their ROM (Table 5). The control group's left legs as a group had improved from the pre-test to the post-test with a mean difference of -5° ± 5.17° (Table 5), also showing a decrease in ROM improvement. The data being decreased in the control group and increased in the experimental group with the improvement of ROM may suggest that the six-week strength training programme made by the researcher in this current intervention study could be the cause of improvement within the participants.

The AROM data is like that of the PROM data where the experimental group had improved their mean difference data from pre-test to post-test. As viewed in Table 6 and Figure 4, the data for the experimental group's right leg mean difference is a 13.7° ± 6.04° improvement in AROM (Table 6). The left leg had an overall mean difference of 12.33° ± 6.39° in the experimental group (Table 6). Compared to this,

the control group had decreased their AROM with a mean difference decrease of -3.8° ± 4.18° in the right leg and -4.2° ± 3.05° in the left leg (Table 6). The two groups may differ in improvement of AROM as the experimental had completed the six-week strength training intervention and the control did not, suggesting the strength training programme used may have contributed to the improvement within the experimental group's AROM scores.

Strength and RT training is known to help with muscle activation [30] which can help activate the muscles surrounding a joint [14] this can help the body move through a greater ROM [75]. In the gym programme created by the researcher, there were exercises such as light stretching and deadlift variations which trained the participants to use their full ROM in strength training. Using full ROM in these exercises can help elongate the muscles which may contribute to an increase in PROM [53]. Viewing another paper using a strength and flexibility intervention programme to improve AROM and PROM [51] shows similar results compared to the current study. In both the current study and the literature review research study, all the participants in the strength conditioning group had improved. The low stretching and full ROM in strength training exercises improve AROM and PROM in the literature review study [51]. In the literature review research study, strength training improved the most in AROM which was a 23% increase from pre- to post-test [51]. In the research previously mentioned, [51] there were similar exercises used such as hip flexor exercises as well as engaging the rest of the legs and the core. It can be suggested that the current study also used an effective strength training programme that improved the PROM and AROM of the experimental group. Strength training has been found in other studies to improve flexibility, PROM and AROM [2, 19, 47, 51, 55, 75]. Therefore, strength training and other RT programmes should be implemented into a dancer's schedule to improve a dancer's ROM. The second objective of the current dissertation has been discussed and an improvement of skill within ROM using a six-week RT intervention programme was found effective in a small young adult female jazz dance population.

4.3.3 Performance

In section 1.4 Dance Performance, it is established that dance performance focuses on visual and emotional aspects for the audience to have an engaged response to choreography [56] and that overall performance is important for both the dancer and the audience [57]. The current literature review in the current dissertation found 5 research papers which used an RT programme to improve performance within dance and all 5 research papers improved [2, 47, 68, 76, 81]. When viewing the data for the PCEM performance scores [58] of the current intervention study, all participants in the experimental group had improved their overall scores from pre-test to post-test with both judges. Due to the inter-rater reliability being 0.82 between both judges' answers, the scores given for both the experimental and control groups were deemed sufficient for substantial agreement. After viewing the data in Table 7 and Figure 5, the experimental group improved their mean value and SD from pre-test to post-test with 7.33 points ± 2.58 points (Table 7). The control group had an M value and SD of 0.4 points ± 0.968 points (Table 7). Identifying that the experimental group had improved with the completion of the strength training programme and the control did not, as well as the 5 research papers in the literature review [2, 47, 68, 76, 81] had all improved in the performance tests used for their respective papers. It can therefore be suggested that RT programmes can improve a dancer's overall

performance. It can be stated however that a final covariant of diet and nutrition should be looked into in future research to help performance as a sportsperson's or dancers' full recovery from training should be accompanied with the correct amount of protein intake for muscle development and recovery [108]. To improve in the future, a food diary could be logged by participants to control this covariant from the results.

In previous literature, it has been established that RT programmes like strength training can increase muscle strength leading to better muscle control over movements and the ability to execute precise movements and choreography effectively [66, 68, 81]. Strength training can also help to improve a dancer's alignment and posture which is crucial for maintaining proper form and enabling efficient movements and aesthetics for the audience [75]. Specific RT programmes tailored to different dance styles can improve a dancer's performance in that particular genre. For example, in ballet, some strength training programmes may focus on the legs and core to improve strength within lifts [78, 85]. In jazz dance, strength training programmes may focus on improving AROM or the alignment in movements to focus on flexibility and ROM used in jazz dance [4].

Other performance research has shown that performance has been improved with the incorporation of RT [2, 47, 68, 76, 81]. Within the research papers in the literature review, RT programmes had improved performance in the populations tested. One study designed a specific test which deducted scores from participants when they were fatigued or ventured too far away from the area they were given to dance in, this study improved upon performance flexibility and strength within its participants [47]. A third study improved power and performance [68] using a reliable performance proficiency tool [66]. The strength training programme was used to identify if performance could be improved among young adult female jazz dancers the experimental group in the current study improved more than the control group. These findings support the theory that RT programmes can improve a dancer's overall performance [2, 47, 68, 76, 81] due to the findings in Table 8. The performance data from the current study has encouraged the answer towards the second objective which is that the improvement of skill within performance using a six-week RT intervention programme on a small young adult female jazz dance population can be beneficial.

4.3.4 Practical Implications

After evaluating data from the six-week strength training intervention, it can be suggested that jazz dancers could possibly implement RT training into their schedule to develop better strength, PROM, AROM and performance. The improved results within the experimental group of the intervention study suggest that using the implementation of an RT programme is better for improving dance training parameters such as strength, ROM and performance than not using an RT programme at all. The covariates of dance experience, RT experience, training programme exercise frequencies, psychological factors and diet and nutritional factors should be controlled by future researchers to understand whether the results are truly due to the intervention itself.

The RT programmes created in future research should complement the movement within the chosen genre and could potentially improve the functional movements of that genre directly.

In using an RT programme like strength training, a dancer can improve their strength and ROM, which allows the technique to be improved and therefore the dancer can execute complex movements with confidence. The improvement in strength and ROM can therefore improve a jazz dancer's overall performance. The successful improvement within the current intervention study can potentially suggest that RT programmes could be incorporated into young adult female jazz dancers' dance schedules.

Chapter 5: Limitations and Summary Chapter

5.1 Literature Review Limitations

There are some limitations in the literature review which may impact the outcomes. Firstly, the research used is mostly qualitative which can lead to some of the research being overly subjective, for this, the qualitative research should be assessed with caution. Secondly, there was a lack of experience from the current researcher and due to the fact, that they are completing a self-taught MPhil some of the research may lack professionalism and thorough understanding. Additionally, there are also gaps in the research for other styles as well as jazz dance so the generalisability of only looking into the jazz dance style may be a limitation for future research. Case reports and interventions that use an experimental and a control group were both used within the literature review. Soley interventions could have been used to solidify data. Some papers used non-randomised controls which can also be a limitation due to the bias of groups. The researcher also did not use a limiting score range from 'Kmet et al.'s, Quality Assessment Tool' [83]. A limited score range of higher-scored papers would have allowed more reliable research to be used in the current literature review. For example, research papers which scored 20 or higher could have been used for the reliability of papers. In the research, the variation of sample sizes makes it difficult to get a concrete answer as some may have anomalies in the results of the study. It is also not effective that some of the studies have low sample sizes as this does not allow the paper to build significant findings from a small sample size. A participant range could have been used for the papers, for example, more than 40 participants. The research could have also used a power analysis to determine generality, and the number of intervention research studies may show the lack of homogenous outcomes that prevented the current researcher from running a Meta-Analysis. A meta-analysis nor a scoping review was completed due to the lack of knowledge from the researcher and the lack of appropriate studies from the search of the literature review.

5.2 Intervention Study Limitations

There are some limitations which may affect the outcomes of the current intervention study, one would be the advertisement of the intervention study towards only two institutions. Advertisement emails were sent out to BOA Alumni, London Studio Centre, Hammond, and Worcester University but no emails were received, or they

were computerised responses back. The total number of advertisements to schools who responded was two, this is a limitation because a variety of dancers could not be tested in various institutions, so a wider range of institutions should be looked into to get a broader range of results from trained participants.

Another limitation was the narrow scope of participants. The researcher needed participants who were female jazz dancers who were in or had just left university training in the last 3 years and they had to have at least 3 years' worth of jazz dance training. The literature review allowed for a broader search of research on all dance genres. The intervention study then focussed on the gap in research in the style of jazz dance which is a narrow scope in the research field. The generalisability of completing the testing only on jazz dance narrows the answers for this research only on the jazz dance genre. Other genres that are less tested such as street dance could be tested in the future to gain more evidence.

In the performance testing, it has been established that there is not one universal scoring system for dance [64] which means the judges may be subjective in their interpretation of marking. The inter-rater reliability was 0.82 and the PCEM scoring system [58] was decided as the best test for this current intervention study as the researcher believed there was less interpretation in these questions to other performance scoring tests.

Due to the lack of time, there was a small cohort of participants for this study, however, there was over double in the second cohort than the first which was a great deal of work for the researcher. The researcher also had a lack of research experience, moving from a Bachelor's of Science to a Master's of Philosophy was difficult for the researcher to teach themselves how to write more academically and how to research with much more information to collect.

The previous covariates: dance experience, RT experience, training programme exercise frequencies, psychological factors and diet and nutritional factors should be taken into consideration for a limitation within this research. In future research, the covariates should be controlled to understand whether the results are truly due to the intervention itself.

15.3 The Master's Process

The master's process was a hard challenge to overcome. The step between a bachelor's and master's is incredibly difficult especially a Master of Philosophy as it is more of a preparation for a doctorate due to the level of self-research that must be done. Although the current researcher had many battles throughout the process such as COVID-19, their grandfather passing away, having to re-sit their dissertation and then finding a similar literature review that had been published with similar ideas to what they were forming. The researcher felt deflated throughout the process but am extremely proud of where they have come from the original hand in, to the resit.

The researcher's supervisory team has been a great help throughout the process and ensured they were there if ever the researcher had a question, emails were always speedy and the team would email back and forth even in their own time which they never had to do, but the researcher is grateful. The start of the study took

a while to write up as it was such an integral part of the study and lots of drafts were sent in. The main changes took place within the intervention study, the participant's exclusion and inclusion criteria were the main part that was mostly adapted as the study had to be opened to not just students but leavers as well because there were not enough participants involved. After the re-sit even more participants had to be found, this was such a challenge for the researcher, but more were found in the end. The researcher understood what they need to do in the future if they were to ever do a doctorate course and that is to network better and advertise the dissertation more around multiple universities and Vocationals. Although the researcher looked in two areas, London and Birmingham, there was still not a huge number of participants; networking should improve this.

The main thing the researcher had to contend with throughout my master's course was the death of their grandfather. They had to take over a 5-month leave of absence as there was a lot of heartache caused by the grandfather's death. The researcher's whole family needed each other at this point so a lot of time was spent grieving. There was an investigation into the grandfather's death at the time, and there is now a court hearing due to the reason for their death. The grandfather's death caused so much distress during the process of the researcher's dissertation, so the absence was necessary to prevent their work from as much harm as possible. However, this leave of absence may have stunted the researcher's achievement in their master's as they were not able to carry on with their academic writing. The researcher had finished all the six-week training intervention programmes and around a month or two later, their grandfather passed. The researcher could not carry on with the flow of creating the research and their studies were paused for a while. The researcher believes their grandfather's death and Leave of Absence (LOA) have stopped the possibility of printing the research as the study is now older than it should have been. However, the researcher feels as though they had to take an LOA to deal with their loss which is still ongoing. The researcher believes that if they had continued without the LOA, they would not have been able to finish the course and maybe even would have had to withdraw from the course. For this reason, the researcher did not want to leave the course, so the LOA was necessary. Also, the researcher believes that the LOA may have disrupted the age of the research. The supervisory team again and the researcher's family were there to support and help push through to get the research done as they know it is integral to the field that more research be created. It is also what the researcher's grandfather would have wanted.

There are also situations that the researcher did not discuss with the supervisory team or university as they do not wish to confide for personal reasons but, it has affected a lot of my mood towards their living conditions and life in general. Progressively, the situation has gotten worse since the re-sit but, it has nothing to do with the re-sit. The researcher is very proud of where their work is at now, so they look at the re-sit positively and they believe their work feels more mature compared to their original hand-in.

Throughout the learning process, the researcher has improved on many skills, especially on the technical side. They have learnt how to calculate P values, and F

values to attain a conclusive hypothesis. They have used new applications such as Python to understand the coding answers needed for a dissertation. They have also improved their Microsoft Word and Excel skills with the help of the supervisory team giving hints and tips throughout the process. Additionally, they have improved their writing skills from their bachelor's degree and understand the structure and layouts of these more. If in the future, the researcher was to ever continue to a Doctorate, they believe they would have the knowledge to do so. The passing of knowledge from their supervisory team has been substantial and they are forever grateful.

Overall, the researcher is happier with their resubmission compared to their original hand-in and they feel as though they are prouder of this current hand-in. The researcher believes the current findings will help add to the current research on the effect RT has on strength, ROM and performance.

Chapter 6: Dissertation Conclusion

The evidence shown in the current literature review shows the positive improvements that strength, flexibility, and ROM have on a dancer's performance. The parameters listed can improve dance performance through the implementation of an RT programme. The 'Kmet et al.'s, Quality Assessment Tool' [83] has scored some papers as more reliable than others in the literature review so the difference in scores needs to be taken into account for any bias in results.

In future research, more studies on different dance styles should be conducted as there is continuous research on the styles of modern dance, contemporary, and ballet, and little research on street dance or jazz dance. The current researcher conducted a six-week RT intervention programme on female jazz dancers which evaluated and identified the improvement of skill within strength, ROM, and performance, this is due to the findings in both the systematic literature review (Table 2) and the P = 0.0001 value for all tests within the intervention study (Table 8). Due to the findings in the intervention study specifically the interpretation of results in Table 8 which shows the significantly positive results from the P values as 0.0001. The current dissertation has an alternative hypothesis of H1 because of the results in Table 8.

Resistance training is beneficial for ballet, modern, contemporary, and now within the cohort of the current jazz dancers used within the intervention study. To gain more understanding of whether it works in more jazz dancers or in other genres such as street dance, a future recommendation should be made for researchers to complete a similar study on various dance genres. The analysis identifies strength, ROM, and performance as key factors in a jazz dancer's training schedule and practical implications should be to incorporate an RT programme tailored well towards the genre of dance researchers, dancers or teachers would like to improve in.

The aims and objectives for this dissertation have both been completed. The first was completed in a literature review where the objective was to identify and evaluate strength, ROM and performance using RT programmes on the dance research population. Due to the findings within Appendix 3, Tables 2, 3, 4 and 5, the literature review has found 15 research papers [2, 6, 19, 46, 47, 51, 55, 61, 68, 75, 76, 78-81]

to solidify the completion of objective one. The second objective was to identify and evaluate the effect of an RT intervention programme on strength, ROM and performance using a young adult female jazz dance population. The results within Table 8 (0.0001) show a significant improvement within the current jazz dance population. The final hypothesis of the intervention study is H1.

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Chapter 9: Appendices

9.1 Appendix 1

Jazz Dance

The definition of jazz dance is widely unknown, and many jazz dance professionals will argue its meaning [22, 23]. The main concepts of jazz dance contain expressions [22-24] gravity and individual style [22]. Some of the main styles used in jazz dance are theatrical jazz dance, which blends ballet, jazz, and other styles to create commercial jazz, and theatrical jazz which is used most commonly in theatres and shows globally [23]. In the school walls, dancers have been taught a version of jazz dance that was influenced by ballet [22].

The origins of jazz dance had accumulated from the style of African [22-24] and European dance [23]. When slavery forced African citizens to vacate their homelands to America, they brought with them their love of music and dance. The mixture of African and European dance had evolved after emancipation [23]. The mixture of styles created the 1900s ‘Jazz Age’ [23]. In the first creations of the style of jazz dance, there were aspects taken from African dance [22-24]. The elements of African dance that are still in jazz dance today are improvisation, competition, and individual style [23]. Throughout the 1920s jazz dance had adapted to dances such as the Charleston [22] and this era created choreographers such as Katerine Dunham who started to change the style of jazz dance to a more theatrical style [20]. Later choreographers such as Bob Fosse were at the forefront and their styles helped create many dance films and theatre shows such as Chicago, All That Jazz, and Cabaret [20, 22]. Today jazz has adapted to the styles of commercial and musical theatre jazz dance [22-24].

The variety of jazz movements that evolve each time makes it difficult to specify certain movements in the jazz dance style [22]. Contrastingly, ballet movements have been around and established for many years with very little change [20, 25]. Even though jazz was around after the citizens of West Africa had incorporated it into the American jazz dance style, there have been many adaptations of jazz dance throughout the years until now [23].

In modern dance, there are similarities between the concepts of jazz and ballet. The origins of modern dance were made by a choreographer called Isadora Duncan who danced in her youth at tea parties around the 1890s and her first performance was in 1902 [26]. Modern dance became more popular among choreographers such as Martha Graham, Merce Cunnigham, and Alvin Ailey who all took the style of ballet dance and rejected the strictness of the style [20]. Nowadays, the modern style still uses the various elements from choreographers who started the style but takes concepts from jazz dance including, individuality and

improvisation as its form but still rejects the restrictions caused by ballet movements [20]. Contemporary dance is similar to modern dance where it takes influence from styles such as ballet and jazz dance but contemporary dance allows more fluidity of movement and reflects on today’s artistic trends [27].

The history behind jazz dance can ensure a clearer understanding of how the performance and theatre style of jazz dance should be improved and developed by science. Improving a dancer's training can be done by incorporating scientific research into a dancer's schedule [3]. The scientific research in question could be an RT programme implemented alongside a dancer’s schedule and tests within ROM, strength, and performance to concur whether dance performance skills have improved [3, 4, 17].

9.2 Appendix 2

'Kmet et al, Quality Assessment Tool' Questions and Scoring Table.

	Criteria	YES (2)	PARTIAL (1)	NO (0)	N/A
1	Question / objective sufficiently described?				
2	Study design evident and appropriate?				
3	Method of subject/comparison group selection or source of information/input variables described and appropriate?				
4	Subject (and comparison group, if applicable) characteristics sufficiently described?				
5	If interventional and random allocation was possible, was it described?				
6	If interventional and blinding of investigators was possible, was it reported?				
7	If interventional and blinding of subjects was possible, was it reported?				
8	Outcome and (if applicable) exposure measure(s) well defined and robust to measurement / misclassification bias? means of assessment reported?				
9	Sample size appropriate?				
10	Analytic methods described/justified and appropriate?				
11	Some estimate of variance is reported for the main results?				
12	Controlled for confounding?				
13	Results reported in sufficient detail?				
14	Conclusions supported by the results?				

9.3 Appendix 3

Kmet et al, 'The Quality Tool Assessment' final scores

Questions:

1. Question / objective sufficiently described?
2. Study design evident and appropriate?
3. Method of subject/comparison group selection or source of information/input variables described and appropriate?
4. Subject (and comparison group, if applicable) characteristics sufficiently described?
5. If interventional and random allocation was possible, was it described?
6. If interventional and blinding of investigators was possible, was it reported?
7. If interventional and blinding of subjects was possible, was it reported?
8. Outcome and (if applicable) exposure measure(s) well defined and robust to measurement / misclassification bias? means of assessment reported?
9. Sample size appropriate?
10. Analytic methods described/justified and appropriate?
11. Some estimate of variance is reported for the main results?
12. Controlled for confounding?
13. Results reported in sufficient detail?
14. Conclusions supported by the results?

	Paper	**Ahearn 2018**				**Angioi 2012**				**Annino 2007**			
Questions		**Yes (2)**	**Partial (1)**	**No (0)**	**N/A**	**Yes (2)**	**Partial (1)**	**No (0)**	**N/A**	**Yes (2)**	**Partial (1)**	**No (0)**	**N/A**
1		2				2				2			
2			1			2				2			
3		2				2				2			
4			1			2				2			
5				0		2				2			
6				0					/				/

7					/				/				/
8		2				2				2			
9			1				1				1		
10			1			2				2			
11				0		2				2			
12			1			2				2			
13			1			2				2			
14		2				2				2			
	Total				**14**				**23**				**23**

	Paper	**Brown 2007**				**DiPasquale 2017**				**Koutedakis 2007**			
Questions		**Yes (2)**	**Partial (1)**	**No (0)**	**N/A**	**Yes (2)**	**Partial (1)**	**No (0)**	**N/A**	**Yes (2)**	**Partial (1)**	**No (0)**	**N/A**
1		2				2				2			
2		2				2				2			
3		2				2				2			
4		2				2				2			
5		2							/	2			
6					/				/				/
7					/				/				/
8		2				2				2			
9			1				1				1		
10		2				2				2			
11		2				2				2			
12		2					1			2			
13		2				2				2			
14		2					1			2			

	Total				**23**				**19**				**23**

	Paper	**Koutedakis 2004**				**Marshall 2012**				**Sanders 2020**			
Questions		**Yes (2)**	**Partial (1)**	**No (0)**	**N/A**	**Yes (2)**	**Partial (1)**	**No (0)**	**N/A**	**Yes (2)**	**Partial (1)**	**No (0)**	**N/A**
1		2				2				2			
2		2				2				2			
3		2				2				2			
4		2				2				2			
5		2				2				1			
6					/				/				/
7					/				/				/
8		2				2				2			
9			1				1					0	
10		2				2				2			
11		2				2				2			
12		2				2				2			
13		2				2				2			
14		2				2				2			
	Total				**23**				**23**				**21**

	Paper	**Stalder 1990**				**Twitchett 2011**				**Vetter 2009**			
Questions		**Yes (2)**	**Partial (1)**	**No (0)**	**N/A**	**Yes (2)**	**Partial (1)**	**No (0)**	**N/A**	**Yes (2)**	**Partial (1)**	**No (0)**	**N/A**
1		2				2				2			

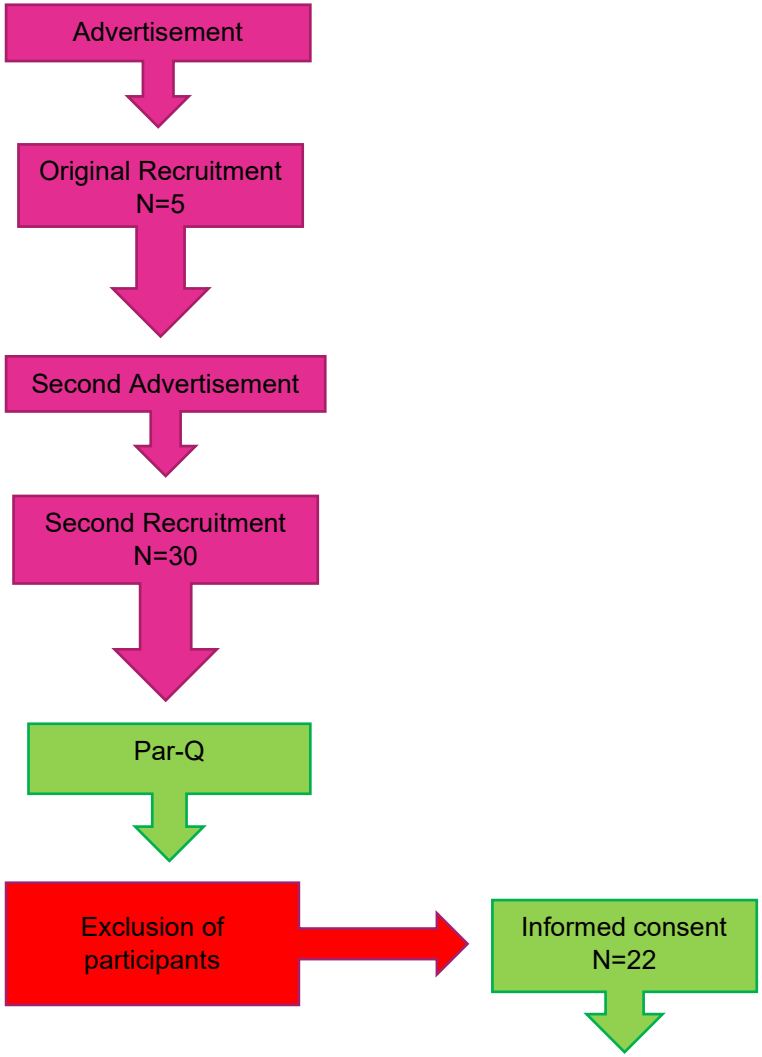
2		2				2					1		
3		2				2				2			
4		2				2				2			
5				0		2						0	
6					/				/				/
7					/				/				/
8		2				2				2			
9			1				1				1		
10		2				2				2			
11		2				2				2			
12			1			2					1		
13		2				2				2			
14			1			2					1		
	Total				**19**				**23**				**18**

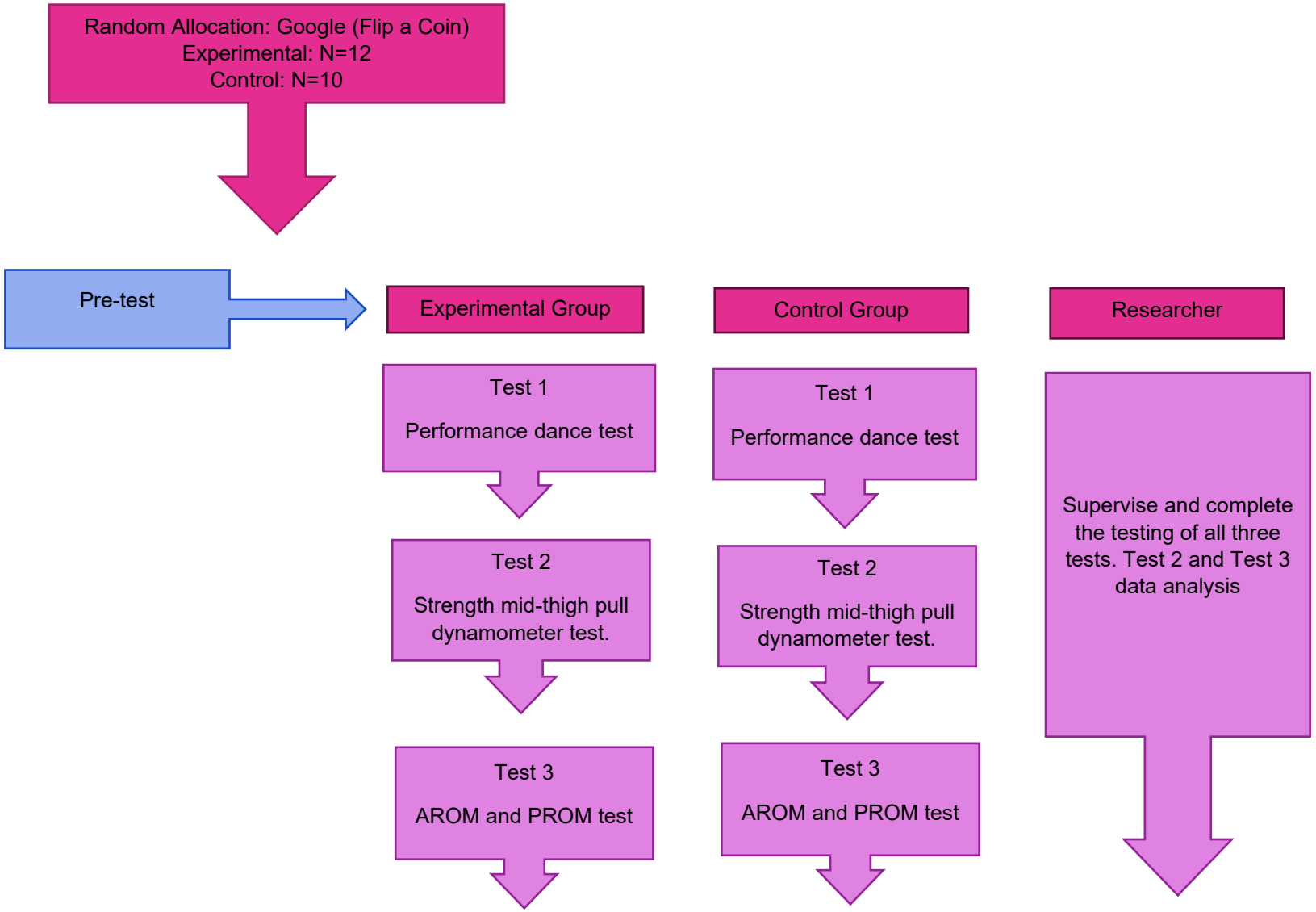
	Paper	**Watson 2017**				**Wyon 2010**				**Wyon 2013**			
Questions		**Yes (2)**	**Partial (1)**	**No (0)**	**N/A**	**Yes (2)**	**Partial (1)**	**No (0)**	**N/A**	**Yes (2)**	**Partial (1)**	**No (0)**	**N/A**
1		2				2				2			
2		2				2				2			
3		2				2				2			
4		2				2				2			
5				0		2				2			
6				0					/				/
7					/				/				/
8		2				2				2			
9			1				1				1		

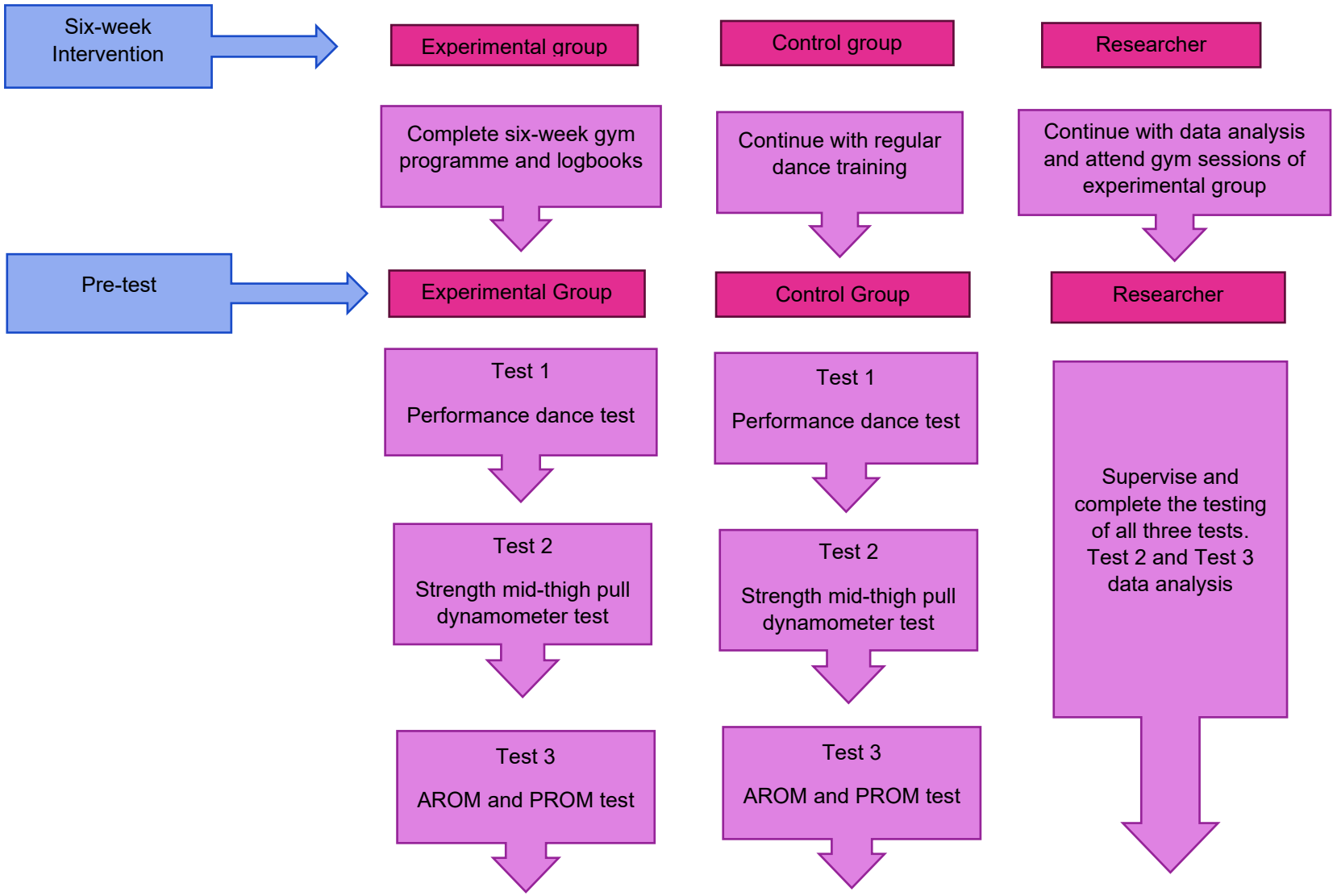
10		2				2				2			
11		2				2				2			
12				0		2				2			
13		2				2				2			
14				0		2				2			
	Total				**17**				**23**				**23**

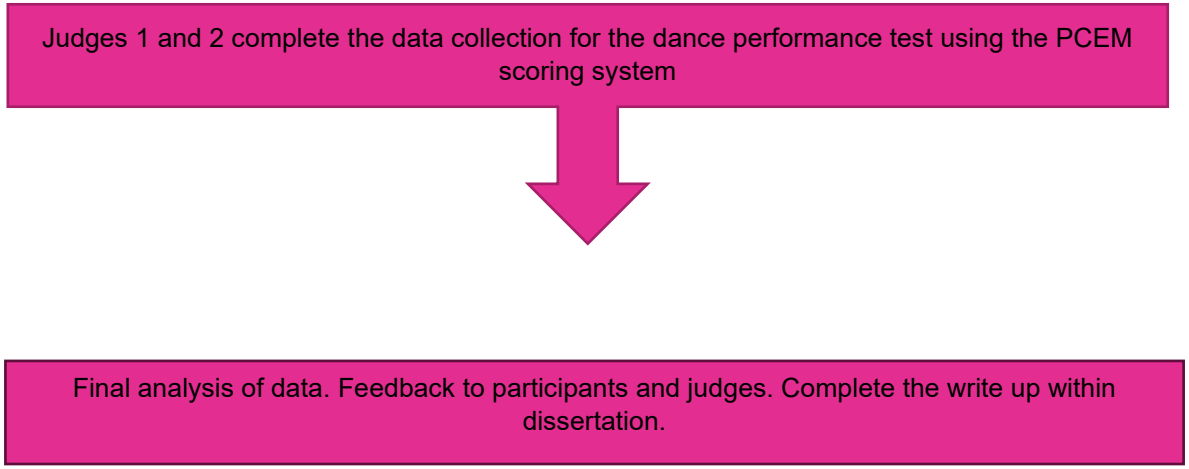
9.4 Appendix 4

Flowchart: which breaks down the steps of advertisement, recruitment, testing and data analysis for the current intervention study.




Random Allocation: Google (Flip a Coin)
Experimental: N=12
Control: N=10
Pre-test
Experimental Group
Control Group
Researcher
Test 1
Performance dance test
Test 2
Strength mid-thigh pull dynamometer test.
Test 3
AROM and PROM test
Test 1
Performance dance test
Test 2
Strength mid-thigh pull dynamometer test.
Test 3
AROM and PROM test
Supervise and complete the testing of all three tests. Test 2 and Test 3 data analysis


Six-week Intervention
Pre-test
Experimental group
Control group
Researcher
Complete six-week gym programme and logbooks
Continue with regular dance training
Continue with data analysis and attend gym sessions of experimental group
Experimental Group
Control Group
Researcher
Test 1
Performance dance test
Test 1
Performance dance test
Supervise and complete the testing of all three tests. Test 2 and Test 3 data analysis
Test 2
Strength mid-thigh pull dynamometer test
Test 2
Strength mid-thigh pull dynamometer test
Test 3
AROM and PROM test
Test 3
AROM and PROM test


Judges 1 and 2 complete the data collection for the dance performance test using the PCEM scoring system
Final analysis of data. Feedback to participants and judges. Complete the write up within dissertation.

9.5 Appendix 5

Krasnow's et al, PCEM guide on how to score participants' performance in dance.

Table 1 Guide for Judges

Full Body Involvement			
	Stabilized Base		
	Axial	Locomotor	Limb Energy
Level I	In off-center torso movements, little or no ability to maintain center of weight over base of support	In off-center torso movements, little or no ability to accurately transfer the center of weight from one support base to the next	Repeated signs of "dead" or unattended body segments when focus of the movement is elsewhere
Level II	In off-center torso movements, demonstrated but inconsistent ability to maintain center of weight over base of support	In off-center torso movements, demonstrated but inconsistent ability to accurately transfer the center of weight from one support base to the next	Occasional displays of "dead" or unattended body segments when focus of the movement is elsewhere
Level III	In off-center torso movements, consistent ability to maintain center of weight over base of support, resulting in great freedom of movement in the torso work	In off-center torso movements, consistent ability to accurately transfer the center of weight from one support base to the next, resulting in great freedom of movement in the torso work	No displays of "dead" or unattended body segments when focus of the movement is elsewhere, resulting in all body segments being energized, regardless of how minimal the movement is
Body Integration and Connectedness			
	Central Energy	Spine Articulation	Relationship of Body Segments
Level I	In isolated limb gestures, little or no central body energy or core support underlying the action	Lack of awareness and sensitivity to articulating various portions of the spine; poor spine sequencing	Poor alignment; appropriate relationship of body segments to each other rarely or never demonstrated in movement phrases
Level II	In isolated limb gestures, occasional but inconsistent central body energy or core support underlying the action	Occasional but inconsistent awareness and sensitivity to articulating various portions of the spine; inconsistent understanding of appropriate spine sequencing	Some alignment problems; appropriate relationship of body segments to each other only occasionally demonstrated clearly in movement phrases
Level III	In isolated limb gestures, consistent central body energy or core support underlying the action	Clear and consistent awareness and sensitivity to articulating various portions of the spine; consistent demonstration of appropriate spine sequencing	Good alignment; well-executed and consistent demonstration of the appropriate relationship of body segments to each other in movement phrases

9.5.1 Appendix 5.1

Krasnow's et al, PCEM guide on how to score participants' performance in dance *(continued)*

Table 1 Guide for Judges (*continued*)

Articulation of Body Segments			
	Lower Limb Activity	Upper Limb Activity	
Level I	Incapacity to generate thigh and leg activity without obvious, undesired movement of the pelvis; poor articulation of the femur in the hip socket, demonstrated by lack of mobility of the femur	Poor articulation of the humerus in the should joint; very limited mobility of the humerus, with no accompanying mobility of the scapula and rib cage to support humeral movement; inability to avoid undesired scapula and rib cage movement during full range humeral movement; poor scapulo-humeral rhythm	
Level II	Occasional inability to generate thigh and leg activity without obvious, undesired movement of the pelvis; restricted articulation of the femur in the hip socket, demonstrated by limited mobility of the femur	Restricted articulation of the humerus in the shoulder joint; limited mobility of the humerus, with inconsistent accompanying mobility of the scapula and rib cage to support humeral movement; occasional ability to avoid undesired scapula and rib cage movement during full range humeral movement; uneven scapulo-humeral rhythm	
Level III	Thigh and leg activity clearly differentiated from the pelvis; excellent articulation of the femur in the hip socket, resulting in the capacity to move the lower limbs with good mobility and no unnecessary pelvic movement	Clear articulation of the humerus in the shoulder joint; good mobility of the humerus, with accompanying mobility of the scapula and rib cage to support humeral movement; clear ability to avoid undesired scapula and rib cage movement during full range humeral movement; good scapulo-humeral rhythm	
Movement Skills			
	Direction Changes	Balancing	Levels, Speed, and Dynamics
Level I	Great difficulty with quick changes of direction, resulting in instability and rhythmic inaccuracy	Little success at sustaining balances in the middle of movement phrases, resulting in repeated loss of concentration on the qualitative aspects of the movement phrase	Sluggish or awkward when attempting shifts in levels, speeds, and/or dynamic qualities
Level II	Some success, but awkward with quick changes of direction, resulting in occasional losses of stability and rhythmic accuracy	Moderate ability to sustain balances in the middle of movement phrases, resulting in occasional loss of concentration on the qualitative aspects of the movement phrase	Unpredictable at achieving clear and appropriate shifts in levels, speeds, and/or dynamic qualities
Level III	Ease at achieving quick changes of direction, resulting in consistent stability and overall rhythmic accuracy	Consistent ability to sustain balances in the middle of movement phrases, resulting in consistent concentration on the qualitative aspects of the movement phrase	Well-executed shifts in levels, speeds, and dynamic qualities, creating transitions which are clear and appropriate for the given material

9.5.2 Appendix 5.2

Krasnow's et al, PCEM guide on how to score participants' performance in dance – score sheet.

Table 2 Score Sheet for Performance Competence Evaluation

Name of Judge_____ Date _____			
Videotape code number_____			
Overall proficiency Rating	1	2	3
Full Body involvement	1	2	3
Evaluation of use of stabilized base, and limb energy			
Body integration and connectedness	1	2	3
Evaluation of central energy, spine articulation, and inter-relationship of body segments			
Articulation of body segments	1	2	3
Evaluation of lower limb activity, and upper limb activity			
Movement Skills	1	2	3
Evaluation of direction changes, balancing, changes in levels, speeds and dynamics			

9.5.3 Appendix 5.3

Krasnow's et al, PCEM guide on how to score participants' performance in dance showing each category.

Table 3 PCEM Scoring System

Levels	Category 1	Category 2	Category 3	Category 4	Baseline points	Total point range
Level 1	1 - 3	1 - 3	1 - 3	1 - 3	0	4 - 12
Level 2	1 - 3	1 - 3	1 - 3	1 - 3	7	11 - 19
Level 3	1 - 3	1 - 3	1 - 3	1 - 3	14	18 - 26

Category 1: Full body involvement in movement; Category 2: Body integration and connectedness in movement; Category 3: Articulation of joints and body segments; Category 4: Movement skills.

9.6 Appendix 6
Gym Programme – Session One Week One

SESSION ONE – Week One, Three and Five

GYM PROGRAMME

WARM UP

Cardio:
Stair Master for 5 mins on medium speed (6-8)
Or
Stair Master moderate interval training:

- 30 secs quick paced [8-10 (not running, brisk steps)]
- 1 min normal paced (5)
- Repeat 3 times.

Or
Incline treadmill: 5 mins quick walk.
Or
Incline moderate interval training:

- Same as above but on running machine.

Mobilisation – 10 of each exercise 1 set each:

- Leg swings, front and back.
- Hip rotations.
- Spine rotations

Dynamic Stretches:

- Walking lunges = 10 reps/4 sets with 30 secs rest between using body weight
- Leg swings = 10 reps/1 set (1 set each leg)
- Hip swings = 10 reps/1 set (1 set each leg)
- Step throughs = 10 reps/1 set
- Squat and reach = 3x 15 secs hold

MAIN EVENT

BEFORE EACH EXERCISE, ENSURE 2 WARM-UP SETS ARE COMPLETED BEFORE. With the warm-up sets, this may be bodyweight squats for example and then a lightly weighted bar before using a lifting bar for the main 4 sets. This applies to every exercise.

Please refer to the video tutorials of the researcher for further help on the form.

Stiff-Legged Deadlift pyramid set:

Perform 12 reps with 60%RM – 30secs – 1min rest.
Perform 10 reps with 70%RM – 30secs – 1min rest.
Perform 8 reps with 80%RM – 30secs – 1min rest.
Perform 10 reps with 70%RM – 30secs – 1min rest.
Perform 12 reps with 60%RM – 30secs – 1min rest.

Exercises	Reps/Sets	RPE (1-10)	Rest Time	Notes
Squats	2 Warm up sets – 6 reps 6 reps/4 sets	Warm-up: 5-6 Main: 7-9 RPE moves up slightly in each set	3-5 mins	Ensure knees shoulder width apart, feet turned out slightly, and bar positioned onto your traps on your back. Chest up and glutes pushed out. Then drive your glutes to the floor whilst keeping your chest up, the bar should stay in one continuous straight line down and up. When you get to the top, squeeze glutes, quads and hamstrings. Repeat.
Stiff-Legged Deadlifts	6 reps/4 sets	Warm-up: 5-6 Main: 7-9 RPE moves up slightly in each set	3-5 mins	Feet shoulder width apart and bring your feet just under the barbell. Ensure when looking down, the bar looks as though it sits where your laces would sit on your trainers. Hinge at the hips and grab the bar, hands shoulder-width apart with an overhand grip. Slightly bend the knees and when ready push shoulder blades back and lift the bar keeping the bar close to your shins and the bar should finish at the hips. Bring the bar back down and hinge the hips back again, keeping the bar in the same motion and just moving your hips back and forth to feel the movement predominantly in the hamstrings.
Leg Press	6 reps/4 sets	Warm-up: 5-6 Main: 7-9 RPE moves up slightly in each set	3-5 mins	Set the seat so that the legs are hitting 90 degrees to start, a tip is to set the seat a little lower to get full ROM within the exercise. Place both feet on the plate and keep them hip-width apart and feet parallel. When ready push off from your feet and perform the reps.

Calf Raises on box	NO WARMUP SET NEEDED 10-14 reps/4 sets	Body weight RPE: 5-6	3-5 mins	Stand on box hip width apart and move yourself backwards so your heels are hovering off the of the box. You can hold a wall in front or to the side for stability. Rise up keeping knees slightly bent and have a straight torso, bring the heels down past the box to hit the anterior tibialis too. Repeat.

COOL DOWN

Foam roll muscles worked:

- Back
- Quads
- Hamstrings
- Glutes
- Abductors
- Adductors

Becky will demonstrate all these in the first session. If you get stuck, you can contact Becky at any point for help.

Stretches: please carry out your normal flexibility stretching routine used for normal dance classes.
Or please follow:

1. 2nd position hands on knees. Push right hand in 30secs then left 30secs.
2. Lunge = hold for 30 secs each leg
3. Lunge with knee on floor = hold 30 secs each leg
4. Lunge side to side = transferring with no hands 30 secs hold each leg
5. Runner's stretch = 30 secs hold each leg
6. Head over legs (hamstring stretch) = hold 30 secs each leg - keep hips square

9.6.1 Appendix 6.1
Gym Programme – Session Two Week Two

SESSION TWO – Weeks Two, Four and Six

GYM PROGRAMME

WARM UP

= Same warm-up as session 1

MAIN EVENT

BEFORE EACH EXERCISE, ENSURE 2 WARM-UP SETS ARE COMPLETED BEFORE. With the warmup sets, this may be bodyweight squats for example and then a lightly weighted bar before using a lifting bar for the main 4 sets. This applies to every exercise.

Please refer to the video tutorials of the researcher for further help on the form.

Conventional Deadlift pyramid set:

Perform 12 reps with 60%RM – 30secs – 1min rest.
Perform 10 reps with 70%RM – 30secs – 1min rest.
Perform 8 reps with 80%RM – 30secs – 1min rest.
Perform 10 reps with 70%RM – 30secs – 1min rest.
Perform 12 reps with 60%RM – 30secs – 1min rest.

Exercises	Reps/Sets	RPE (1-10)	Rest Time	Notes
Conventional Deadlifts	6 reps/4 sets	Warm-up: 5-6 Main: 7-9 RPE moves up slightly in each set	3-5 mins	Feet shoulder width apart and bring feet just under the barbell. Ensure when looking down, the bar looks as though it sits where your laces would sit on your trainers. Squat down to the bar and grab the bar with an overhand grip. Push chest out and keep head up. From this position, lift the bar up to your hips. Ensure you drive your bum up and under and stand up straight. Keep the barbell as close to your shins as possible. Once at the hips, drive the hips back and return to the squat like position at the start. Keep the barbell as close to your shins as possible each rep squeeze glutes and erector spinae at top and repeat.
Walking Lunges	6-10 reps/4 sets	Warm-up: 5-6 Main: 7-9 RPE moves up slightly in each set	3-5 mins	After warm-up sets, grab the dumbbells you will be using and hold them at your sides. Walk one foot forward as straight as possible from the starting position and bend both knees so they are in a 90-degree angle. Keep your torso up. Bring the back foot into the front foot and walk past it as though walking, bend down into 90-degree angles from here again and repeat.
Glute Bridges	6 reps/4 sets	Warm-up: 5-6 Main: 7-9 RPE moves up slightly in each set	3-5 mins	Grab a bench and barbell and set up equipment. Once set up, sit to one side on the bench and ensure barbell can sit comfortably on your hip bones during exercise. Ensure you start on the bench just below the shoulder blades, you may have to lift up a bit for this from sitting, then once in this position and the barbell is on your hips/lap comfortably, drive your hips up to the ceiling which would make your shoulder blades come into contact with the bench. Squeeze your glutes at the top and drive back down to starting position. Repeat.
Leg Raises on Bench	6 reps/4 sets	5-6	3-5 mins	Grab a bench and lie down so that your glutes are slightly off the bench. Hold the top of the bench with your arms and make sure your torso is straight. Extend your legs out straight and keeps them together, you can have a slight bend at the knees. Contact your legs up using your hip flexors before you hit 90-degree and squeeze your hip flexors at the top before lowering your legs. Do not put your feet on the floor and continuously move the legs. Your legs should come 2 seconds up and 4 seconds down. Repeat.

COOL DOWN = Same cool down as session 1.