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Pain, Function and Trunk/Hip Flexibility Changes Immediately after Clinical Pilates Exercises in Young Adults with Mild Chronic Low Back Pain

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Abstract: Background: Pilates is among the best conservative management strategies for chronic low back pain. However, several variations of Pilates exist. This study aimed to investigate physical measures that would detect immediate changes after a brief session of Clinical Pilates exercises. Changes in self-reported clinical outcomes, pain and function were also evaluated. Methods: A prospective cohort study was conducted. Eighteen young adults with chronic low back pain participated in this study. Participants were assessed for pain and function subjectively, and hip/knee strength and trunk/hip flexibility objectively, followed by a session of Clinical Pilates assessment and exercises. After the exercises, the participants were immediately reassessed for pain, function, strength, and flexibility. Results: Trunk/hip flexibility showed statistically significant changes after exercise, which were measured with the sit-and-reach test (−3.44 cm, 95% CI [−5.10, −1.79], $p < 0.001$) and the finger-to-floor test (−6.29 cm [−9.51, −3.06], $p = 0.001$). Statistical significance was not found in detecting strength changes in hip extension, hip abduction, and knee extension. Changes in pain (1.56 points [0.83, 2.28], $p < 0.001$) and patient-specific functional scale (−1.52 points [−1.93, −1.10], $p < 0.001$) were also found after exercise. Conclusions: Trunk/hip flexibility measures detected physical changes after Clinical Pilates exercise, as well as self-reported pain and function outcomes, without reducing strength performance.

Keywords: lumbopelvic; hamstring flexibility; strength; disability; rehabilitation; physiotherapy

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1. Introduction

The prevalence of low back pain (LBP) is high among adults [1]. LBP stands out as one of the most commonly seen musculoskeletal pain in primary care [2]. Compared to adolescents, there is a higher incidence of low back pain among young adults [3]. Most LBP diagnoses do not have specific causes, which makes treatment decisions challenging [4]. Although most LBP cases tend to recover naturally, some of those who recover would experience LBP again, which is usually mild in nature [5]. Chronic LBP puts a strain on global health, with the years lived with disability increasing by 17.2% from 2005 to 2015 [6,7]. Exercise continues to be a recommended conservative approach to manage chronic LBP [8]. Recent studies have shown that Pilates exercises are among the most effective approaches for managing chronic LBP [9–11]. However, several variations of Pilates approaches exist, and translating them to clinical practice can be daunting if there are challenges in replicating the methods used in these interventions.

The Dance Medicine Australia (DMA) Clinical Pilates approach is a technique recognized by physiotherapists worldwide, and its assessment and treatment methods are aligned with physiotherapy practice [12]. General Pilates exercises involve movements in all directions, which include movements that trigger pain in an individual with LBP. In contrast, DMA Clinical Pilates exercises are prescribed if they are easy to perform and do not aggravate pain or symptoms, also known as movement preference exercises. The movement-based classification of the DMA Clinical Pilates approach has a strong emphasis on shortening the assessment duration and using minimal but critical information to guide the exercise prescription plan [12]. Directional (or movement) preference was studied previously to demonstrate its importance, with researchers cautioning against prescribing exercises involving unfavorable movements that would lead to detrimental functional performance [13]. A recent study showed that movement preference could also exist in relatively healthy individuals, as well as those who had recovered from injuries [14]. The translation of the DMA Clinical Pilates intervention to broader clinical practice was limited by a study that found the approach similar to general exercises comprising aerobic and strengthening exercises for pain and function among adults with chronic LBP [15]. However, it was noted that the Clinical Pilates exercise prescription approach used in that past study did not fully adopt the principles of the DMA Clinical Pilates approach. Furthermore, freshly trained researchers were recruited to assess and treat the study participants immediately [15]; this greatly impacted the credibility of the approach, which requires clinical experience and completing a certification examination to achieve optimal application and treatment efficacy [13]. Currently, the literature that is representative of the DMA Clinical Pilates approach for managing LBP is limited.

The strength of the lower limb muscles can influence lower back function due to their proximal position. A recent study highlighted the importance of hip and knee strengthening exercises to reduce pain and improve functioning among adult runners with chronic LBP [16]. However, research has not shown whether a low-intensity Clinical Pilates intervention has effects on strength. Apart from lower limb strength, back flexibility is also an issue affecting individuals with LBP [17]; thus, reduced trunk/hip flexibility can be a useful movement-based clinical outcome measure. Individuals with more trunk flexion mobility are less likely to experience LBP [18]. A past study showed that mat work Pilates exercises improved lumbopelvic flexibility [19], whereas a recent equipment-based Pilates study showed reduced flexibility [20]. It is possible that increased loading with Pilates equipment during exercises could improve strength and reduce flexibility. However, it is unclear if the flexibility gained through mat work Pilates exercises would be detrimental to strength. Current evaluations of treatment efficacy are dependent on subjective self-reported outcome measures [21], which may lack objectivity. Of interest, we hypothesized that movement-specific exercises using the DMA Clinical Pilates approach would lead to improved lumbopelvic flexibility without a significant reduction in hip and knee strength.

The current literature investigating the DMA Clinical Pilates approach for the management of LBP is scarce. We hypothesize that individualized DMA Clinical Pilates exercises can reduce self-reported pain and improve function. Therefore, this study was undertaken to investigate the effects of DMA Clinical Pilates exercises on improving pain and function and explore if there would be changes in strength and flexibility after a brief session of Clinical Pilates exercises.

2. Materials and Methods

2.1. Study Design

A prospective cohort study was conducted from May 2021 to June 2022. Data collection was conducted by RHRT for strength measurements and self-reported outcome measures, while LYT performed flexibility measurements. A physiotherapist certified in DMA Clinical Pilates with more than 10 years of clinical experience (BCK) carried out the intervention. The study was approved by the Institutional Review Board of the Singapore Institute of Technology, SIT-IRB-2021026. The study was retrospectively registered on the Australian New Zealand Clinical Trials Registry, ACTRN12624000182594.

2.2. Participants

Participants were recruited from the Singapore Institute of Technology through email circulars and from the public by word of mouth. All participants provided signed informed consent before the commencement of the study. The inclusion and exclusion criteria were adapted from a previous study [15]. The study included adults aged 21 years and above with existing LBP lasting for at least three months, with mild LBP (less than 5/10 on the Visual Analog Scale). Participants were excluded from the study if they had lower limb injury in the past six weeks, surgery in the past three months, lower limb fracture in the past year, neurological, inflammatory, or malignant conditions, cognitive or visual impairments, ongoing fever or infection, unexplained weight loss or loss of appetite in the past three months, loss of bladder/bowel control or saddle paresthesia, known pregnancy, recent exercise intervention in the past three months, and/or uncontrolled medical condition. The participant flowchart is presented in Figure 1.

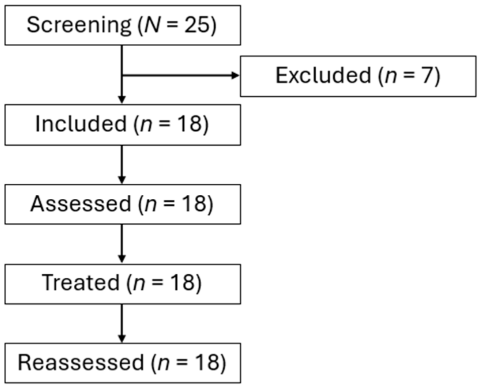

Figure 1. Study participant flowchart.

2.3. Outcome Measures

2.3.1. Self-Reported Outcomes

The study evaluated changes in the self-reported outcomes of pain and function with an interview approach to standardize the interpretation of pain and functional limitations across participants. Participants were asked to rate their pain intensity at the point of assessment on a Likert scale, the Visual Analog Scale, scored from 0 to 10, where "0" represented no pain and "10" represented worst pain [22]. Physical function was assessed using the Patient Specific Functional Scale (PSFS) [23]. Participants were asked to rate their ability to complete two or more activities that were limited by their LBP on an 11-point Likert scale, where "0" represented inability to perform the activity and "10" represented ability to perform the activity at pre-pain levels. The PSFS scores were totaled and divided by the number of activity limitations reported.

2.3.2. Physical Strength Outcomes

The study was limited to the investigation of three main muscle groups (hip extensors, hip abductors and knee extensors) because of potential testing fatigue. The study adopted an isometric strength testing approach where participants were asked to exert maximum force and sustain muscle contraction for five seconds. A handheld dynamometer (HHD), the clinical gold standard, was used to quantify the maximum force (N) exerted by the participants. The HHD was attached to a gait belt to resist the movement for five seconds while the assessor maintained the position of the HHD. Each muscle group was tested twice with a one-minute rest interval between trials. As some participants might experience fatigue with repeated testing while others might benefit through the learning effect, we selected the trial with the highest force from the two trials for data analysis. The testing position followed the HHD-belt protocol [24]—(1) for hip extension, the HHD was placed at the distal posterior thigh with the participant in prone and extending the hip with the knee fully extended throughout the test; (2) for hip abduction, the HHD was placed 1 cm above the lateral epicondyle of the knee with the participant lying on the non-test side, hip and knee slightly flexed on the non-test leg, and with participants abducting their hip while maintaining full knee extension throughout the test; (3) for knee extension, the HHD was placed at the distal tibia with the participant sitting with their hip and knee flexed at 90 degrees and extending their knee against the fixated HHD. To test knee extensors, the participants were instructed to cross their arms on their chest, and a towel was placed below the distal thigh of the tested leg to maintain 90 degrees of hip flexion.

2.3.3. Flexibility Outcomes

Lumbopelvic–hip flexibility was measured with the sit-and-reach test (SRT) and finger-to-floor test (FTFT). Similar to the strength testing protocol, a one-minute rest interval was given to each participant between trials and tests. We considered the possibility that some participants might exhibit improved flexibility while others might respond with tensioning with repeated stretch tests. Hence, the better measurement among the two trials for each test was used for data analysis. The SRT was performed with a sit-and-reach box (Sit n' Reach Trunk Flexibility Box, Baseline, United States of America), and participants were positioned in long sitting with their backs against a flat concrete wall, knees fully extended, feet placed shoulder-width apart and feet flat against the box. The participants then leaned forward as far as they could reach, keeping their knees fully extended throughout the test [25], as shown in Figure 2. The FTFT was performed with each participant standing on a wooden rehabilitation stepping board (18 cm height) with pre-marked locations demarcating foot placement for standardization across all participants. The participant then leaned forward to reach for the floor with knees maintained in full extension [19], as shown in Figure 3. As shown in Figure 3, the measurement would be recorded as −20 cm. If the participant was able to reach beyond the toe level, the measurement would be recorded in the range of 0 to 18 cm.

Figure 2. End-position of the sit-and-reach test.

Figure 3. End-position of the finger-to-floor test.

2.4. Intervention

Before receiving the intervention, all participants were assessed between 10 and 15 min with the DMA Clinical Pilates approach [12], which was essential to identify the problem side for exercise prescription. The assessment involved charting pain regions on the body chart alongside other bodily symptoms, followed by recording easing and aggravating factors of the LBP and history of trauma. This was then followed by the lumbar movement assessment while standing to determine flexion, extension, lateral flexion to each side, and rotation to each side. Finally, an exercise-based assessment was conducted to confirm the hypothesized side and direction of treatment. Exercise movement coupling involves either flexion or extension, left or right lateral flexion, left or right rotation, or a combination of two to three directional movements. For example, a combination of flexion and right lateral flexion indicates two directional movement axes. After exercise testing was completed with the DMA Clinical Pilates approach, the problem side of a participant was confirmed. It is important to note that the painful side does not always dictate the problem side; similarly, participants with central or both-sided pain would not provide valuable information to hypothesize the potential side that is a problem. Thereafter, the participants were prescribed one to four exercises at three sets of 10 repetitions or two sets of 15 repetitions per exercise. The exercises were completed between 10 and 20 min, depending on the number of exercises prescribed. Exercises were prescribed only for one side and were either single-step movements (Stage 1) or multiple-step movements (Stage 2). Exercise intensity was maintained within two to four on a 10-point Borg's Rate of Perceived Exertion scale. It is pertinent to note that only mat exercises from the DMA Clinical Pilates approach were used in this study.

The participants first began with natural or relaxed breathing in a supine position on an exercise mat. The DMA Clinical Pilates flexion exercises used in this study included roll up, heel slide, bug leg, hundreds, cat stretch, spine stretch, single leg stretch, circles, leg press, and knee drop, while extension exercises included prone single leg kick, cobra, front support (floor/wall), thigh stretch, 4-point kneel, side-lying back kick, and lastly, close-chain squats to mimic open-chain (or modified close-chain) bunny hop exercise on the lower bar of the trapeze bed. Exercises for lateral flexion included supine clams (if hip adductor impairment was present), side-lying clams (if hip abductor impairment was present), mermaid (the treatment side is on top), and side lunges (the treatment side being the side with the knee extended). For instance, in the mermaid exercise, treating the left side will require the individual to lie on the right side and lift the pelvis off the ground, similar to a side bridge exercise. Lateral flexion exercises can be adjusted based on flexion or extension directional preference [14]. This is in contrast to the traditional strengthening program, where the side requiring treatment is positioned at the bottom. The rotation exercises included in the study were supine rotation (flat back) for mid-range flexion or extension preference: bug roll and corkscrew for full flexion preference, and attitude rotation and kneeling rotation for full extension preference. In terms of supine exercises, such as supine rotation, bug roll and corkscrew, it is important to note that turning the leg to the left creates right trunk rotation and vice versa. On the other hand, attitude rotation, which is performed prone, involves moving the left leg to the right to create right trunk rotation and vice versa. Upon completion of the prescribed exercises, participants were then reassessed for their strength and flexibility outcome measures.

2.5. Sample Size

Due to the exploratory design of this study to investigate strength and flexibility changes, we used the current clinical standard, pain score changes, to guide sample size calculation. Based on a past study, the minimal detectable change of pain score changes was 33% [26], which translated to a large effect size [27]. Taking into consideration that the objective measures of interest might have a smaller effect size, we estimate the effect size to be moderate to large, which is 0.65. Using G*Power version 3.1.9.4 at 80% power and type I error at 5%, with a two-tailed paired sample *t*-test, the sample size required was calculated to be 21 participants.

2.6. Statistical Analyses

The study population was characterized by age, gender, anthropometrics, level of fear avoidance, level of physical activity participation, and the Oswestry Disability Index. Continuous variables were presented in means (standard deviations), and categorical variables were presented in counts (percentages). The data for strength outcomes were classified into the problem and non-problem side for statistical analysis. The classification was based on assessment findings from the DMA Clinical Pilates assessment. To compare changes between pre- and post-intervention, a paired sample *t*-test was used. Statistical analyses were performed using IBM SPSS Statistics for Windows, version 26 (IBM Corp., Armonk, NY, USA). Statistical significance was set at $p < 0.05$.

3. Results

This study screened a total of 30 adults with chronic low back pain, and 18 of them met the criteria for study participation. There were no study dropouts or missing data. The study demographics are summarized in Table 1. The 18 young adult participants presented with mild to moderate pain and minimal disability. Half of the participants did not meet the World Health Organization's minimum weekly physical activity recommendation. The duration of LBP among the participants ranged from 3 months to 7 years. Eight participants presented with one-sided pain, five participants presented with pain on both sides, and five participants presented with central pain.

Table 1. Study characteristics (n = 18).

Demographics	Distribution
Age, years, mean (SD)	23.1 (1.8)
Gender, female, n (%)	12 (66.67)
Body weight, kg, mean (SD)	65.06 (11.65)
Height, m, mean (SD)	1.67 (0.06)
Body mass index, kg/m^2, mean (SD)	23.41 (3.79)
Fear-Avoidance Beliefs Questionnaire—Physical activity, /24, mean (SD)	11.28 (5.42)
International Physical Activity Questionnaire—short, n (%)	
Low	9 (50)
Moderate	7 (38.9)
High	2 (11.1)
Oswestry Disability Index, %, mean (SD)	12.79 (5.87)

Changes in the outcome measures post-intervention are presented in Table 2. Immediately after a brief DMA Clinical Pilates intervention, participants experienced a reduction in pain, with an average of a 1.56-point reduction on the visual analog scale, $p < 0.001$, and better functioning on the PSFS, with an average of 1.52 point improvement, $p < 0.001$. Changes after a brief session of DMA Clinical Pilates exercises were also detected with flexibility outcome measures, with an average of 3.44 cm gain in SRT flexibility, $p < 0.001$, and an average of 6.29 cm gain in FTFT flexibility, $p = 0.001$. Additionally, the exercises prescribed did not result in a statistically significant decrease in the isometric strength of the hip extensors and abductors or a statistically significant increase in knee extensor isometric strength.

Table 2. Pre-post intervention outcome measures changes (*n* = 18).

Outcome Measures	Time-Points, Mean (SD) Pre	Time-Points, Mean (SD) Post	Mean Difference (SD)	95% CI	*p*-Value
Self-reported					
Pain visual analog scale, /10	2.22 (1.87)	0.67 (1.03)	1.56 (1.46)	0.83 to 2.28	<0.001
Patient-specific functional scale, /10	6.36 (1.40)	7.88 (0.98)	−1.52 (0.83)	−1.93 to −1.10	<0.001
Strength—problem side					
Hip extensors, N	198.08 (79.73)	192.92 (70.68)	5.16 (34.46)	−11.98 to 22.29	0.534
Hip abductors, N	225.64 (77.64)	227.81 (84.20)	−2.17 (33.63)	−18.90 to 14.55	0.787
Knee extensors, N	220.93 (71.98)	236.88 (75.35)	−15.94 (38.80)	−35.24 to 3.35	0.099
Strength—non-problem side					
Hip extensors, N	204.83 (63.45)	195.08 (63.21)	9.74 (42.74)	−11.51 to 31.00	0.347
Hip abductors, N	237.93 (95.62)	226.73 (72.18)	11.19 (37.52)	−7.46 to 29.85	0.223
Knee extensors, N	224.76 (44.33)	234.27 (79.32)	−9.52 (44.36)	−31.58 to 12.54	0.375
Flexibility					
Sit-and-reach test, cm	24.06 (7.99)	27.50 (6.51)	−3.44 (3.33)	−5.10 to −1.79	<0.001
Finger-to-floor test, cm	−10.42 (12.80)	−4.13 (9.57)	−6.29 (6.49)	−9.51 to −3.06	0.001

4. Discussion

This study was primarily conducted to investigate changes in self-reported pain and function, hip extensor and abductor isometric strength, knee extensor isometric strength, and lumbopelvic–hip flexibility (SRT and FTFT) immediately after participants received a session of DMA Clinical Pilates exercises. Lumbopelvic–hip flexibility measures showed significant improvement, while the hip and knee strength measures did not. Self-reported measures of pain and function yielded statistically and clinically meaningful changes post-intervention. The findings of this study indicated that mat work motor control exercises that were specific to directional preference and side impairment improved trunk/hip flexibility without an adverse effect on hip and knee strength.

In this study, pain and function improved after a single session of low-intensity mat work using DMA Clinical Pilates exercises that were easy to perform and were similar to a study that intervened twice a week over 6 weeks [15]. Our findings suggest that the efficacy of DMA Clinical Pilates was immediate, providing quicker pain relief and faster functional recovery. These benefits might be related to the exercises being pleasant to do as they did not provoke pain or discomfort. Effective mat work exercises could empower patients to continue with home exercises with increased compliance, which was found to be related to improved self-efficacy in a recent study [28]. Past studies evaluated meaningful changes in pain scores of 1.8 to 2.4 points amongst people who experienced moderate pain [29–31], whereas our study included people with mild pain; therefore, the improvements in our study could be considered clinically meaningful. The goal of rehabilitation is to minimize participation limitations in the World Health Organization's International Classification of Functioning and Disability [32]. Our study yielded meaningful improvements to functioning that exceeded the minimally clinically important change of the PSFS [29]. The use of the DMA Clinical Pilates approach is thus a cost-saving strategy for healthcare settings impacted by long appointment lead times. In the future, these findings could be meaningful for policymakers in developing strategies to achieve better health outcomes in a shorter period of time.

In our study, we found that flexibility changes could be improved after a session of DMA Clinical Pilates exercises without significantly affecting the hip extensor and abductor isometric strength of the participants. Although there was a trend in improved knee extensor isometric strength, the change was not statistically significant. The FTFT improvements yielded greater changes as compared to the SRT. This could be attributed to the difficulty in monitoring whether the knees remained fully extended as the thigh and leg were not firmly supported to prevent any compensatory movement at the knees. Hence, the difference in distance changes between the FTFT and the SRT might imply that the relaxation of the hamstrings at the distal portion could have contributed to the increase in measurement obtained with the FTFT method. Another possible explanation for the difference between methods could be attributed to parallax error in distance measurement with the FTFT method. Future measurements of the FTFT could consider the use of digital tape measure using a laser beam to minimize potential measurement error.

The improvements in flexibility measures could be attributed to the similarity of movements in Pilates exercises with ballistic stretching exercises. Ballistic stretching exercises have been shown to improve flexibility without reducing strength as compared to static stretching exercises [33]. The flexibility changes detected in our study are closely to the changes found in a study using a mat work Pilates intervention [19]. In contrast, general Pilates exercises performed with resistance resulted in reduced flexibility [20]. A possible explanation for the lack of changes in strength might be attributed to peripheral neuromuscular fatigue. Research has shown that exercises lasting for more than six minutes, including low-intensity exercises, can deplete glycogen storage, inhibit intracellular calcium ion release, and reduce channel sensitivity, thus impairing subsequent force production [34]. Recovering fully from peripheral neuromuscular fatigue requires at least 20 min [34]. Additionally, to improve strength, resistance training is essential for significant strength changes [35], but in our study, the participants were prescribed mat work exercises without resistance bands. Future studies could consider the use of resistance bands for mat work exercises if strength is a designated outcome measure.

This study had several limitations. First, improvements in self-reported outcomes could be attributed to the placebo effect, as participants might perceive improvements when treatment is provided [36]. This study evaluated the acute effects of DMA Clinical Pilates exercises on lower limb strength, trunk/hip flexibility, pain and function, so future studies could explore potential longer-term benefits. Second, we studied relatively young adults, so generalizing the study findings to middle or older adults requires careful consideration. This study used general lumbopelvic–hip flexibility tests, so the findings can be a result of changes at the trunk, hip, hamstrings, or a combination of them. Hence, future studies should consider assessing lumbar flexion and hamstring flexibility separately. Third, the changes observed in this study might be influenced by other factors as the study did not include a control arm. Lastly, this study was conducted during the pandemic and had to be concluded before we could achieve the estimated sample size. Nonetheless, based on the effect size of our study findings, the sample size was determined to be sufficient in detecting changes in the self-reported outcomes and flexibility measures. A recent study suggests that technology could play an important role in pain management [37]. The systematic approach of the DMA Clinical Pilates assessment could be progressed with the aid of artificial intelligence to facilitate self-assessment among people with LBP, which could then develop specific exercise plans that benefit the users. Future studies could undertake a randomized controlled trial design with a larger study sample size to further validate the study findings.

5. Conclusions

Overall, our study showed that measures of trunk/hip flexibility using SRT and FTFT methods showed improvements among young adults with mild chronic LBP after receiving a session of individualized DMA Clinical Pilates exercises. The SRT method is preferred because the method provides more stabilization to the knees and is potentially more reliable than the FTFT method. The improvements in pain and functioning found in our study suggested that the DMA Clinical Pilates exercises were efficient in managing people with chronic LBP, even though the pain intensities were low.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Research data are not available publicly in accordance with the Personal Data Protection Act. Upon reasonable request, the data may be obtained through the corresponding author within a 10-year period from the published date of the article.

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