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Hong Kong Physiotherapy Journal

Aims & Scope

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Experiences of occupational health doctors and nurses about the role of physiotherapists in occupational health rehabilitation: A qualitative study

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Background: Occupational health physiotherapy has been practiced in the UK over several decades. In the past decade, the role of occupational health physiotherapy has gained recognition as a profession that can be embedded within occupational health departments; however, limited information is known about the role of physiotherapists from professional groups outside the allied health domain in this context.
Objective: The aim of this study is to explore the experiences of occupational health doctors and nurses about the role of physiotherapy in occupational health rehabilitation.
Methods: This study is a qualitative investigation underpinned by an interpretative construct. Thirteen semi-structured interviews were conducted. Two occupational health doctors and 12 nurses were purposively recruited from two National Health Service (NHS) hospitals. Data were analyzed using thematic content analysis, coded manually and verified by member checking.
Results: The benefits of occupational health physiotherapists were rapid access intervention, advanced knowledge and clinical reasoning, evidence-based practice, and providing an additional perspective. The emerging themes of the challenges that occupational health physiotherapists may face include dealing with occupational health challenges, managing role conflicts, personal qualities and attributes, and role substitution.
Conclusion: Participants described numerous roles of occupational health physiotherapists ranging from clinical to organizational components. On-going research is needed to support the role development of physiotherapists providing occupational health rehabilitation and to further advocate for its relevance in this setting.

Keywords: Physiotherapy; occupational health; rehabilitation; role; experiences.

Introduction

Occupational health physiotherapy as a distinct discipline has been practiced in the United Kingdom since the 1940s.[1] Occupational health physiotherapists are often described as clinicians dedicated to managing employees either autonomously or in conjunction with other members of the team.[2] Traditionally, occupational health physiotherapy falls under the umbrella of musculoskeletal physiotherapy as an advanced practitioner status due to the specialist knowledge and experience required in this specialty. However, the 'advanced' roles in which physiotherapists practice in the occupational health setting is generally poorly documented in the literature. Furthermore, there is no evidence about the experiences of occupational health doctors and nurses with the contribution of physiotherapy to occupational health rehabilitation.[3]

Occupational health doctors and nurses are core professions within the occupational health team and their specialist roles involve reducing the incidence of diseases and injuries, alleviating suffering and promoting and protecting the health and well-being of people in the workplace.[4] Their experiences with occupational health physiotherapy may reflect different insights of the role and could be used to help guide and market it among members of the occupational health team and to clients and commissioners. Their insights could also aid the acceptability of physiotherapy practice in occupational health rehabilitation where there is resistance and guide future training of physiotherapists working in occupational health rehabilitation.

The aim of this study was therefore to explore the experiences of occupational health doctors and nurses about the role of physiotherapists in occupational health rehabilitation.

Methods

Study design

This study used a qualitative framework and was underpinned by an interpretative construct.[5,6] The qualitative approach allows the researcher to explore in-depth the experiences of occupational health doctors and nurses about the role of physiotherapists providing occupational health rehabilitation at two National Health Service (NHS) hospitals in the United Kingdom.[5] The interpretative construct allowed for meaningful engagement and dialogue with occupational health doctors and nurses and provides a unique opportunity to gather new insights about how they viewed the role of physiotherapists in this setting.[6]

The selection of study sites

This study was undertaken at two NHS hospitals of which both offered in-house occupational health services. The two NHS hospitals were strategically chosen because the researcher is not employed by these hospitals and does not line manage any member of the occupational health team. This eliminates the effects of coercion and conflicts of interest and provides the researcher with an outsider's perspective. The outsider's perspective is advantageous because the qualitative researcher should preferably enter the research setting as a stranger so that the setting can be viewed with greater insight and more sensitivity not having been decreased by familiarity.[7] However, an outsider needs to take more time to establish trust with participants which may delay the research.[7]

These two NHS hospitals are comparable in terms of size, bed availability, number of staff employed and patient throughput. Both also feature similar services and have the same structural problems in that they have a combination of century-old buildings and new buildings. Each NHS hospital serves a very different population, with one situated in an affluent area serving a largely homogenous population while the other serving a more culturally diverse population and is situated in a relatively deprived area.

Participants

Permission was sought from the occupational health manager at each NHS hospital in order to inform them of the study and to gain access to the research sites and recruit participants. A date and time to attend one of their team meetings was agreed with each manager. At each team meeting, the researcher met with members of the occupational health team to explain the details of the study and to hand out study packs to participants. Purposive sampling was used to recruit participants to allow for the selection of only those participants that were considered suitable to the study. The recruitment process involved taking into account the professional group and those with at least three years of occupational health experience. Each study pack consisted of an information sheet, consent form and a prepaid return envelope. Study packs were left with each manager to hand to those participants that were deemed as potentially suitable for the study but were not present at the team meeting. Participants were excluded if they were unwilling or unable, for any reason, to give their written consent. Two occupational health doctors and 12 nurses returned their signed consent form and were included in the study.

Data collection

Data were collected using semi-structured interviews. Each participant was interviewed in a confidential room onsite. The duration of each interview lasted up to an hour. At the start of the interview, the researcher confirmed if the participant was still willing to take part in the study. The researcher also explained the purpose of the study and reassured participants that all information gathered during the interview would be handled confidentially. In addition, participants were informed that the interviews will be audiotape recorded to permit data analysis at a later point. The interview questions were open-ended to allow for fundamental lines of enquiry relevant to the topic to be pursued with each participant, while also allowing participants the flexibility to freely expand on questions.[6]

In order to gather in-depth insights of the role of physiotherapists in occupational health rehabilitation, the following questions and prompts were formulated: (1) Can you tell me about your experiences with the physiotherapist who provides occupational health rehabilitation? (Prompts: knowledge, behaviors and skills; differences from general outpatient physiotherapy); (2) What kind of services do you expect a physiotherapist in occupational health to offer you? (Prompts: areas of practice; clinical skills; organizational responsibilities); (3) What do you expect physiotherapists in occupational health to offer occupational health services? (Prompts: expert opinion; new/innovative ways of working; on team, clients, managers and outcomes).

Data analysis

Interviews were transcribed verbatim by the researcher and then independently transcribed by another researcher to ensure accuracy of transcription. Any discrepancies in transcription were resolved by discussion. Thematic content analysis was used to analyze the data. Content analysis is a process of identifying, coding and categorizing the primary patterns of data.[7] The transcriptions were carefully and repeatedly read, with initial ideas being noted. A list of all ideas was made and similar topics were coded and grouped together to form the main themes. Topics not forming part of the main themes were refined into relevant subthemes. Quotes from the original transcript were 'lifted' and arranged under the relevant subtheme. A second reviewer independently reviewed the data and themes and any discrepancies in interpretation were resolved by discussion. The second reviewer was not inhibited by closeness to the study and therefore was able to view the data with real detachment and provide a fresh perspective.[8]

Trustworthiness of the study

Rigor was ensured through credibility, transferability, dependability and confirmability. The researcher built trust by explaining to participants the purpose of the study, utilization and dissemination of the information. Regular notes were kept in a diary to reflect on any emerging assumptions. Thick descriptions were used to enable readers to compare the inferences in the data with those they have seen in their own situation and determine how far they can be confident in transferring to their situation the findings of the study. A detailed description of the study's operational details was provided. The study was described in as much detail as possible to form an audit trail so that readers could trace step-by-step the decisions made. Finally, data trustworthiness was established through a process of member checking whereby all participants were sent their interview transcripts for review and allowed to make modifications prior to data analysis to ensure its authenticity. No participant asked for any changes or modifications to be made to their transcripts.

Ethical approval

Ethical clearance was obtained from Middlesex University London Health and Social Care Ethics Committee (Reference: MH35). This study did not require NHS ethical review under the terms of the

Governance Arrangements for Research Ethics Committees (A Harmonized Edition) (Reference: 16/SS/0043).

Findings

The characteristics of participants are presented in Table 1. Participants discussed several components about the role of physiotherapists in occupational health rehabilitation. A list of the themes and sub-themes that emerged is presented in Table 2.

Theme 1: Benefits of Occupational Health Physiotherapy

The four sub-themes under this theme are: (1) rapid access intervention; (2) advanced knowledge and clinical reasoning; (3) evidence-based practice; and (4) providing an additional perspective.

Rapid access intervention

Participants recognized that early contact with physiotherapists could yield benefits:

> "*The fact that we have an occupational health physio on-site helps us manage cases much faster, especially those that come in with acute injuries.*" (Case 1, OH Nurse 2).

> "*I would like to have physios in occupational health, especially with all the injuries coming in. It would be really nice if we could have access to physios sooner.*" (Case 2, OH Nurse 3).

Advanced knowledge and clinical reasoning

Physiotherapists have advanced levels of knowledge and clinical reasoning in complex cases:

> "*Physiotherapists provide high-quality and systematic assessments and interventions.*

Table 1. Characteristics of participants.

Site	Occupation	Gender	Experience	Employment status
Case 1	OH Doctor	Male	25 years	Part-time
	OH Nurse	Female	16 years	Part-time
	OH Nurse	Female	8 years	Full-time
	OH Nurse	Female	4 years	Part-time
	OH Nurse	Female	5 years	Full-time
	OH Nurse	Female	12 years	Full-time
	OH Nurse	Female	3 years	Full-time
	OH Nurse	Male	3 years	Full-time
	OH Nurse	Female	6 years	Full-time
Case 2	OH Doctor	Female	14 years	Part-time
	OH Nurse	Female	13 years	Full-time
	OH Nurse	Male	8 years	Full-time
	OH Nurse	Female	17 years	Full-time
	OH Nurse	Female	12 years	Full-time

Table 2. List of themes and sub-themes.

Theme 1:	Benefits of occupational health physiotherapy
Sub-themes:	° Rapid access intervention
	° Advanced knowledge and clinical reasoning
	° Evidence-based practice
	° Providing an additional perspective
Theme 2:	Challenges of occupational health physiotherapy
Sub-themes:	° Dealing with occupational health challenges
	° Managing role conflict
	° Personal qualities and attributes
	° Role substitution

We call on them to problem solve complex cases, especially when we cannot sometimes make a decision ourselves." (Case 1, OH Doctor).

"*We don't expect the physiotherapist to provide a generalist role. We have an occupational health physio in the department because they have very specific knowledge, so you get to tap into that knowledge to get a better idea of how injured the employee really is.*" (Case 1, OH Nurse 5).

Occupational health physiotherapists provide more specialized information compared to occupational health doctors and nurses:

"*Sometimes, as a nurse, we are unable to provide the level of detail the employer wants. We tend to give only general advice, like for back pain we say keep active and don't do any heavy manual handling work, then the employer says that the staff member is already doing this and they want more specific advice. I think there is a need for having physios in occupational health departments who are better placed to deal with these types of cases.*" (Case 2, OH Nurse 1).

"*They are able to evaluate in such detail the effectiveness of interventions, so they are best placed to provide an accurate picture and opinion about how to reduce work injuries.*" (Case 1, OH Nurse 7).

Evidence-based practice

Participants felt that physiotherapists were better able to refine and implement evidence-based protocols:

"*I think physios are often better at simplifying the evidence and the general consensus is that they tend to use it more often.*" (Case 1, OH Doctor).

"*Physios tend to follow protocols, so they don't miss anything. I guess they are keen for everyone to be treated according to a standard.*" (Case 1, OH Nurse 6).

One occupational health doctor viewed their workload as being too high and unpredictable to follow guidelines strictly. They felt that physiotherapists had more time to offer dedicated treatment according to evidence-based protocols:

"*A lot of the time, clients prefer to see the physio because they know what to say and do at week 1 of the injury and then week 2 and then a few weeks later. If I see the same client, they don't get the same type of advice ... we doctors tend to give the same advice ... we are probably not as consistent in our advice as physiotherapists.*" (Case 2, OH Doctor).

Occupational health nurses were of the view that physiotherapists not only improve the quality of care provided to clients, but also provide an evidence-based influence on the organization:

"*The physio does not only provide care to our clients, they also deal with issues within the organisation. I think it's very important they get involved at this level because they have all this knowledge about anatomy and physiology and they can justify why we say what we say ... if that makes sense.*" (Case 1, OH Nurse 1).

"*I suppose that physios are more involved than we are in assessing because they understand things like human function. We would probably just give clients a back booklet, whereas the physio would know what the latest information is and how to translate this into organisational requirements. We sort of get the ball rolling ... they are the ones with all the fancy interventions.*" (Case 2, OH Nurse 2).

Providing an additional perspective

Participants expected physiotherapists to provide an additional perspective in selected occupational health cases:

"*It is better to have physios because they can offer more expertise, which I find compliments the doctor's advice.*" (Case 1, OH Nurse 4).

"*I think the more specialists there are on the team to assist staff with all sorts of conditions, the better ... this will ensure that staff get better care, so I think physiotherapists can help make care better.*" (Case 2, OH Nurse 1).

Physiotherapists were also expected to work in collaboration with occupational health doctors and nurses and not in isolation:

"*Physiotherapists would need to liaise directly with doctors and nurses if they want to offer a different opinion so that any disagreement can* *be resolved and the best advice is given to staff.*" (Case 1, OH Nurse 3).

"*There is no doubt in my mind that physiotherapists have unique skills, so having them around makes the occupational health service more complete because they can supply more input into the cases, which the doctors might not have thought about.*" (Case 1, OH Nurse 4).

Theme 2: Challenges of Occupational Health Physiotherapy

The four sub-themes under this theme are: (1) dealing with occupational health challenges; (2) managing role conflicts; (3) personal qualities and attributes; and (4) role substitution.

Dealing with occupational health challenges

Participants agreed that occupational health departments' deal with many challenges and physiotherapists had a crucial role in helping to alleviate some of these challenges, such as the long waiting times and limited departmental resources:

"*One of the crucial issues in occupational health is the waiting times ... and the nurses are so busy with other things ... they don't always have the time to deal with all of this. I think this is where the physiotherapist comes in ... helping to reduce the wait to be seen.*" (Case 1, OH Nurse 2).

Another challenge was the lack of specialized clinicians dealing with certain cases and the multiple problems presenting to occupational health departments:

..."*especially for the acute musculoskeletal cases, I don't think the nurses and even the doctors are skilled enough to deal with some of these. The physiotherapist can help with early management to resolve these injuries.*" (Case 1, OH Nurse 4).

Managing role conflicts

Some occupational health doctors and nurses viewed the advancement of physiotherapy's role in occupational health departments as a potential threat. Some occupational doctors and nurses were concerned that an advancing physiotherapy role could make it more difficult for them to justify their own positions:

"*There seems to be no structure these days about who does what ... our roles seems to be getting blurred all the time, first with nurse-led services and now with the addition of physiotherapists. It's very difficult to say I'm a consultant and I do this because the physios and the nurses do it as well.*" (Case 2, OH Doctor).

"*I think if doctors do their bit, nurses do their bit and similarly physios do their bit, and we all work closely together, then it really works well. I think it's only a problem when some professions try to go beyond what they are trained to do.*" (Case 2, OH Nurse 1).

Although choosing the best candidate for a role is logical, the general view of the physiotherapy role was that it would suit someone who was aware that their role was constantly under scrutiny by other professions within the team and that they had to constantly clarify their position within the team:

"*As an occupational health nurse I have to constantly clarify my position and show the value and attributes I bring to the post. Occupational health physiotherapists are not traditional members of the team, and so it is easy to get a bit confused about their special traits.*" (Case 1, OH Nurse 8).

Personal qualities and attributes

There were certain professional and personal attributes that physiotherapists are required to possess. This involved being able to competently perform a range of physiotherapeutic treatment modalities, have good time management and can demonstrate conflict resolution skills. These attributes were even part of the recruitment process:

"*While it is important to get someone with a range of skills, I think it is also necessary to get someone that has the attributes to cope with the demands of the job and be able to deal with difficult managers.*" (Case 1, OH Nurse 5).

Role substitution

Physiotherapists were also required to occasionally substitute for the role of an occupational health doctor or nurse as they acknowledged that physiotherapists had similar skills and knowledge:

> "*We had a client who was having trouble with his hip and he didn't need to see the doctor because the physio could assess and tell his manager he could come back to work and what should be avoided. So he really didn't need to see the doctor.*" (Case 1, OH Nurse 2).

> "*I see no reason why a physiotherapist cannot reassure staff and tell them how to deal with their injuries. Clients don't need to wait for the nurse or doctor.*" (Case 2, OH Nurse 4).

Discussion

The aim of this study was to explore the experiences of occupational health doctors and nurses about the role of physiotherapists providing occupational health rehabilitation. A higher number of nurses participated in this study which is in keeping with the higher number of nurses employed in occupational health departments. The semi-structured interviews were designed in a way that all participants were asked similar questions while allowing for more in-depth probing to cover a wide range of topics about the role of physiotherapists providing occupational health rehabilitation.

Occupational health doctors and nurses reported several benefits of physiotherapists providing occupational health rehabilitation. In particular, rapid access to physiotherapists was perceived as beneficial to clients attending an occupational health service so that they do not have to wait in long queues for access to primary care physiotherapy. Furthermore, rapid access to physiotherapy services is a national occupational health service quality requirement[8] and physiotherapists should be mindful that occupational health doctors and nurses expect clients to have early access to their services to avoid being perceived as providing an inefficient service. A study by Addley *et al.* on the benefits of a rapid access physiotherapy service in an occupational health setting found significant improvements in health outcomes and enabled those absent from work to return to work earlier.[9]

The advanced level of knowledge and clinical reasoning of physiotherapists in occupational health, beyond that of a generalist physiotherapist, was perceived as an essential component of occupational health physiotherapy practice. This advanced level of knowledge and reasoning is required because physiotherapists in occupational health must provide an expert opinion on both clinical and organizational issues. One of the most effective means of reducing resistance to a physiotherapy role and showing it can make a difference is demonstrating clinical effectiveness.[10] Some of the occupational health clinicians interviewed accepted they had limited knowledge with regards to musculoskeletal injuries and it could be argued that physiotherapists add value to the occupational health service by providing advanced knowledge and reasoning in the rehabilitation of these injuries.

The ability of physiotherapists to provide an additional perspective within an occupational health department was seen as an important role to help filter the referrals coming into the service. This would involve identifying those that are at high risk, those with complex injuries and may have difficulty performing their job, and those that are potentially at risk of sustaining injuries. Arguably, one of the most important contributions that physiotherapists can make to an occupational health department is providing appropriate advice following a referral in order to avoid inappropriate use of occupational health doctors and nurses' time, in particular occupational health doctors, to focus on complex medical cases. Phillips *et al.* evaluated the cost-effectiveness of physiotherapy support for NHS occupational health services and found that physiotherapists were not only skilled to deal with a range of musculoskeletal disorders of the back, neck and upper and lower limbs, but this service had a cost benefit which represents value for money.[11]

Occupational health doctors and nurses also reported challenges that physiotherapists may experience when providing occupational health rehabilitation. Participants viewed the occupational health department as a complex working environment that is influenced not only by clinical care, but by demanding occupational health challenges and organizational changes. In order to address these challenges, participants felt that physiotherapists must be able to balance their clinical role while meeting organizational needs and be able to deal with the presenting occupational health challenges. This will enhance the influence and effectiveness of occupational health physiotherapists on decision makers.[12]

Participants anticipated that physiotherapists who were part of the occupational health department may experience role conflicts with the traditional members of the occupational health team. In the context of this study, role identity is conceptualized as the character people play (that is, the occupational health physiotherapist) when holding specific social positions in groups (that is, the occupational health team).[13] Furthermore, according to Burke and Stets (2009) it is relational, since people interact with each other via their own role identities. In this regard, the physiotherapist who is part of the occupational health team has the advantage of being constantly visible and easier to access with the traditional members of the team to make certain there is a collective agreement on the role of the physiotherapy and reduce any role conflicts. It will also ensure that the physiotherapist is able to promote health and injury prevention strategies from a rehabilitation perspective.[14]

The experience of participants was that although choosing the most appropriately qualified and experienced candidate for a role is logical, the recruitment of the occupational health physiotherapy role is such that it would suit someone who can demonstrate awareness that their role is constantly under scrutiny by other professions within the team. This involves having to constantly clarify their position in the department, and being able to challenge medical opinions and those of the referring manager, especially when it was contradictory to their own professional recommendations.

It is also vital for physiotherapists to demonstrate an advance level of clinical knowledge and reasoning because this may assist with fostering trust, respect and acceptance in occupational health departments. Some participants felt that it was vital for physiotherapists working in occupational health rehabilitation to demonstrate an advance level of clinical knowledge and reasoning because it may allow them to confidently undertake some of the work traditionally performed by occupational health doctors and nurses. However, there was concern that physiotherapists must receive adequate training to carry out any new components in their role so that they do not risk practicing outside the scope of their knowledge.

There were some participants, however, that were concerned about the advanced clinical role that occupational health physiotherapists were performing, and how it threatened their own roles. Reed *et al.* (2009) did warn that when dealing with different stakeholders, conflicting and diverse agendas would come up and this had to be addressed. This is supported by the literature which recognizes that positive outcomes are at risk if departmental staff do not work together to reduce clinical errors.[15] Furthermore, according to Atwal and Caldwell (2002), understanding the roles of each other is essential to effectively collaborate on clinical management and avoid duplication of professional roles, waste resources and miss clinical signs in the interest of protecting clinical turf.[16]

The limitation of the study is its generalizability given the restriction of the study to only two NHS hospitals. Although only two cases were used, it is also an example of a broader group, and therefore offers the prospect of transferability in which readers can judge for themselves the applicability of the findings to their own settings and context.

Conclusion

The analysis of the qualitative data produced subthemes that can be applied immediately to physiotherapy practice within occupational health departments and can be used to further advocate for its relevance in this setting. From the insights of occupational health doctors and nurses, physiotherapists embedded within the occupational health team is likely to accomplish the key elements of a safe, effective and quality occupational health service. Given the importance of team integration, future research should incorporate various other stakeholders to ascertain the role of physiotherapists within occupational health rehabilitation. This information may then be used to build on the sub-themes generated in this study and can be used to promote awareness of the contribution of physiotherapists in line with the intended direction of occupational health services.

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Conflict of Interest

The author has no conflicts of interest to declare.

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Responsiveness of pain, functional capacity tests, and disability level in individuals with chronic nonspecific low back pain

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Background: Clinical outcomes are very important in clinical assessment, and responsiveness is a component inside the outcome measures that needs to be investigated, particularly in chronic nonspecific low back pain (CNSLBP).
Objective: This study aimed to investigate the responsiveness of pain, functional capacity tests, and disability in individuals with CNSLBP.
Methods: Twenty subjects were assessed in pain using the following methods: visual analog scale (VAS) and numeric pain rating scale (NPRS), functional capacity tests: functional reach test (FRT), five-time sit-to-stand test (5 TSST), and two-minute step test (2 MST), and disability level: modified Oswestry Disability Questionnaire (MODQ), Thai version before and after 2-week intervention session. For interventions, the subjects received education, spinal manipulative therapy, and individual therapeutic exercise twice a week, for a total of two weeks. The statistics analyzed were change scores, effect size (ES), and standardized response mean (SRM).
Results: The most responsive parameter for individuals with CNSLBP was pain as measured by numeric pain rating scale (NPRS) (ES −0.986, SRM −0.928) and five-time sit-to-stand test (5 TSST) (SRM −0.846).
Conclusion: This study found that NPRS pain and 5 TSST were responsive in individuals with CNSLBP at two weeks after the beginning of interventions.

Keywords: Back pain; functional; test; capacity; sensitivity; disability.

*Corresponding author.

Introduction

Low back pain (LBP) is a major health problem internationally characterized by a range of biophysical, psychological, and social dimensions affecting functioning, societal participation, and personal financial prosperity.[1,2] The reported prevalence of LBP was high, especially for chronic nonspecific low back pain (CNSLBP), approximately 15.4% (Ref. 3) of which chronic low back pain was about 2.5 times more prevalent in working population compared to nonworking group.[4] Nonspecific low back pain is labeled so when the specific nociceptive source cannot be found[5] while chronic is defined so when the duration that the pain persists is longer than 3 months.[6] As aforementioned impacts are caused by LBP, the outcome assessments for individuals with LBP should therefore cover pain assessment, and also related activities and disability.

Responsiveness is very important for clinicians to consider when the outcome measures are used clinically, by which the responsiveness is the ability of the outcome measures to detect the patient's recovery or health status over time.[7] The recommended methods for statistical analysis to represent the responsiveness consist of change score, effect size (ES), and standardized response mean (SRM).[8–11] It has been reported that for the individuals with acute nonspecific low back pain, the responsive outcomes were pain and disability as reported with ES. In addition, it was found that most of the patients recovered in 2 weeks,[12] to be comparable to the patients with acute LBP, the duration of 2 weeks between the baseline and after-intervention assessments gains attention for the study in the patients with chronic LBP. For patients with chronic LBP, the responsiveness has been studied in various outcome measures such as SF-36 and cooperative (COOP) chart system,[13] Oswestry Disability Index (ODI), EuroQol (EQ-5D), and Shuttle Walking Test (SWT).[14] However, the previous studies had the heterogeneity of the recruited patients, different time interval examinations, and various statistical analyses.[13,14] In addition, the test such as SWT has some limitations for clinical use because of the acceptability to patients and the cost for administration.[14] However, the functional tests are very important for the assessment because they can represent the individual's capacity for performing particular activities. The concepts of functional capacity tests have been developed by Simmonds *et al.*, by using the standardized pattern of functional tests, while minimal equipment is needed and the administration and interpretation are simple. The exemplary functional capacity tests are functional reach test (FRT), 5 TSST, and 2 MST.[15] These functional capacity tests have advantages for clinical use, but the responsiveness of each test needs to be investigated.

This study was therefore conducted to examine the responsiveness of pain, functional capacity test, and disability level in individuals with CNSLBP on 2-week interval of pre-test and post-test assessments for determining the responsiveness of the selected clinical outcome measures.

Materials and Methods

Subjects

Twenty individuals with CNSLBP with the duration of their symptoms being at least 3 months with mild to moderate pain intensity (1–6 cm on visual analog scale, VAS) were recruited from Physical Therapy Center, Faculty of Physical Therapy, Mahidol University. The exclusion criteria were specific for radicular LBP, neurological or cardiovascular diseases, history of previous surgery at the spine or lower extremity, pregnancy, and on menstruation. Written informed consent was obtained from each individual before participation. The study protocol and informed consent have been approved by Mahidol University-Central Institutional Review Board (MU-CIRB), COA no. 2017/155.2808.

Outcome measures

Pain intensity: Visual analog scale (VAS) with 10 cm horizontal line anchored by 'no pain' on the left end and 'worst pain imaginable' on the right was used. NPRS from 0 to 10 representing pain intensity verbally was also used in this study.[16,17] The individuals with CNSLBP reported their pain intensity on worst movement or activity on the tested day by marking on VAS and verbal expression for NPRS.

Functional capacity tests

There were three functional capacity tests in this study comprising functional reach test, five-time sit-to-stand test, and two-minute step test. The individuals with CNSLBP in comfortable clothes and canvas shoes were given an explaination and saw the demonstration before the test.

FRT was used for assessing dynamic balance and flexibility of the trunk muscle. The researcher attached a ruler to the wall at participant's shoulder height and provided feet placement marks on the floor. The individuals with CNSLBP stood sideways next to the wall without leaning against the wall, feet apart as shoulder width, and raised both hands to 90°, kept elbows straight and hands fisting and the 3rd metacarpal head on the ruler was recorded as the starting position. They were then instructed to reach forward with arm outstretched remaining in shoulder height, as far as possible without stepping three times, the best distance reached was then recorded.[18]

5 TSST was used for assessing back and lower limb strength. The researcher placed a chair against the wall for fixing the tested location. The individuals with CNSLBP were seated in the middle of the chair, back straight without support on the backrest and feet flat on the ground, both arms crossed to the chest. They were instructed to rise to fully stand and then returned to a fully seated position as fast as possible five times. The time spent to complete five times was recorded.[19]

2 MST was used to measure the endurance during dynamic weight shifting activity. The researcher measured the stepping height of each individual which was equal to the mid-thigh level, halfway between the iliac crest and patella, and marked the level on the wall. The individual was then informed to step in the provided place with moving the knee up to the predetermined mark on the wall alternately, started with the right leg and continued as many steps as possible within 2 minutes. The researcher counted the number of times the right knee reached the mark. If needed, the individual could be allowed to place one hand on the table for balance.[19]

Disability level: The total score of modified Oswestry Disability Questionnaire (MODQ), Thai version, has been used by summarizing from 10 items; pain intensity, personal care, lifting, walking, sitting, standing, sleeping, social life, traveling, employment/home making, which is categorized into 6 levels of each item starting from 0 (no disability) to 5 (highest disability) and multiplied with two to gain the percentage of disability level.[20] It can imply how pain affects various activities of daily living.[20–22] The higher percentage represented a greater level of disability defined as follows: 0–20 minimal disability, 21–40 moderate disability, 41–60 severe disability, 61–80 crippled, and 81–100 bed bound or symptom magnifier.[21]

Procedures

The individuals were assessed two times, the first time was at the beginning of the intervention program, baseline or pre-test assessment. The second was at the end of the 2-week program, post-test assessment. The assessments were pain intensity during worst movement by VAS and NPRS, functional capacity tests comprising FRT 5 TSST, and 2 MST, and disability level by MODQ, Thai version. All assessments had been done by a physical therapist who has been trained for all assessments for 1 week of didactic period and training session before this study. After finishing pre-test assessment, the results were taken away and kept by another researcher. The physical therapy intervention program was conducted in interim between the two-time assessments. The intervention program comprising education, spinal manipulative therapy and therapeutic exercise[23] including stretching and strengthening for lower back twice a week lasted for two weeks.

Statistical analysis

The descriptive statistics for demographic data of the subjects were shown in number, means and standard deviations, and percentage. The responsiveness in this study consisted of change score, effect size, and standardized response mean. Change scores were calculated by subtracting post-test value from pre-test value, representing the magnitude of the difference between pre-test and post-test, the greater the magnitude, the greater the responsiveness or change. In this study, the change score was calculated as post-test data minus baseline data. ES has been recommended for determining the responsiveness.[24] The calculation is the change score divided by standard deviation of the baseline score,[25] the value below 0.2 is considered small, 0.5 moderate, and 0.8 large according to previous studies.[8,10,11] SRM is similar to ES, which is calculated by the change score divided by standard deviation of the change. Therefore, SRM indicates an estimate of change, which is standardized relative to the variability in change scores. The consideration for the calculated values is the same as ES, or 0.2, 0.5, and 0.8 representing small, moderate, and large, respectively.[9] To compare the change scores between VAS and NPRS, the independent t-test was used since the data were normally distributed with SPSS program version 23 (IBM Corp., Armonk, NY), the statistical significance was set at p-value less than 0.05.

Results

Demographic data of all subjects are reported in Table 1. Baseline and post-test data of the subjects are shown in Table 2. The results of change score, ES, and SRM for all parameters are provided in Table 3. The change scores of pain intensity were −1.3 cm and −1.6 cm in VAS and NPRS, respectively. The change scores of functional capacity tests were 0.9 cm for FRT, −1.5 s for 5TSST, and 14.5 repetitions for 2MST, respectively. The change score of disability as measured by MODQ total score was −5.1%.

For the ES, the most responsive parameters were pain measured by NPRS (ES = −0.986), and VAS (ES = −0.789). While 5TSST had the highest responsiveness for functional capacity test (ES = −0.510).

For the SRM, the most responsive parameter was NPRS (SRM = −0.928), followed by 5TSST (SRM = −0.846), and VAS (SRM = −0.781).

Table 1. Demographic data of the subjects.

Characteristics	Summary
Female/Male, number	13/7
Age, years	43.15 ± 2.03
Weight, kg	57.80 ± 2.06
Height, cm	161.40 ± 1.69
BMI, kg/m^2	22.18 ± 0.60
Duration of symptom, months	32.30 ± 35.50
Location of LBP, %	
Left or Right	35%
Left side	
Right side	20%
Both sides or Centralized	45%
Sacroiliac joint involvement	
Yes	15%
No	85%
Working tasks, %	
Doing housework	10%
Working in prolonged sitting	65%
Working in prolonged standing	25%

Table 2. Baseline and post-test data of the subjects.

Parameters	Baseline	Post-test
Pain		
Visual analog scale (VAS), cm	3.2 ± 1.6	1.9 ± 1.9
Numeric pain rating scale (NPRS), (0–10)	4.0 ± 1.6	2.4 ± 1.9
Functional capacity test		
Functional reach test (FRT), cm	34.4 ± 5.7	35.3 ± 6.1
Five-time sit to stand test (5 TSST), sec	11.3 ± 3.0	9.8 ± 3.2
Two-minute step test (2 MST), rep	77.4 ± 34.0	91.9 ± 23.7
Disability		
MODQ total score, %	14.0 ± 11.3	8.9 ± 7.9

Table 3. Change score, effect size, and standardized response mean of each parameter.

Parameters	Change score	Effect size	Standardized response mean
Visual analog scale (VAS)	−1.3	−0.789	−0.781
Numeric pain rating scale (NPRS)	−1.6	−0.986	−0.928
Functional reach test (FRT)	0.9	0.158	0.184
Five-time sit to stand test (5 TSST)	−1.5	−0.510	−0.846
Two-minute step test (2 MST)	14.5	0.424	0.583
MODQ total score	−5.1	−0.448	−0.487

The comparison of the change scores between VAS and NPRS showed no significant difference, $t = 0.559$, p-value was 0.580.

Discussion

This study aimed to investigate the responsiveness of clinical outcomes regarding pain, functional capacity tests, and disability level in individuals with CNSLBP over the period of 2weeks. The results of this study showed that pain as reported by VAS and NPRS were responsive according to their change scores, ES, and SRM. Using Cohen's suggestions,[8] the value of 0.8 or more is considered large for ES and SRM. The ES and SRM of NPRS were −0.986 and −0.928, respectively. These values were therefore construed as large and responsive. While VAS was little lower than NPRS in terms of change score, ES, and SRM. However, the comparison of the change scores between VAS and NPRS showed no significant difference. In addition, it has been proved that VAS and NPRS have good agreement when using both in acute pain assessment.[26] The pain assessment in patients with chronic LBP contains multiple factors. This study therefore used the functional capacity tests and the disability level additionally for better understanding of the changes in the patients with CNSLBP.

The functional capacity tests, according to SRM, 5TSST were proved to be most responsive rather than FRT and two-minute step test. This result might be because 5TSST involves the strength of knee extensor in performing standing up together with the activity of back extensor muscles for adjusting the trunk upright by extensor moment.[27] This responsiveness could be hypothesized such that the function of back extensor muscles was perhaps better at the post-test examination on the period of 2 weeks owing to decreased pain contributing to increased speed of movement, however, the change of back extensor strength should be investigated for further study.

While FRT and 2MST had small to moderate responsiveness reported as ES and SRM. FRT involves the dynamic postural control for shifting the center of mass (COM) towards the front edge of the base of support as needed.[18,28] Also, 2MST was used to investigate the dynamic postural control together with aerobic endurance requiring weight shifting, lower limb movement, and stability of the spine.[19] Their lower responsiveness results could indicate that the improvement of dynamic postural control needs longer period than 2 weeks for this training in individuals with CNSLBP, the results therefore suggested the practitioners or therapists to understand the recovery and set proper therapeutic time frame since the responsiveness in dynamic postural control would take longer time to follow-up as measured by FRT and 2 MST. In addition, the intervention program in this study did not include the dynamic postural control training, the active portion of the program was back stretching and strengthening exercise. The small responsiveness data might represent the exercise specificity while the back strengthening exercise had minimal cross-over effect to dynamic postural control. The intervention program for future study might include also the dynamic postural control training if the assessment pertaining to the dynamic postural control is included.

For disability level, the responsiveness data using MODQ total score as reported with change score, ES, and SRM were -5.1, -0.448, and -0.487, respectively, which were smaller than the previous study[12] with change score -16.2 and ES -0.930. The result could clearly be concluded as that the individuals with CNSLBP had slower recovery as represented by decreased disability level. Therefore, the future study should provide longer duration of post-test assessment for better result of responsiveness in disability level. This study was designed to be 2-week interval assessment in order to be comparable to the previous study,[12] by which using the same methods of statistical analysis for responsiveness, also, the clinical setting and intervention program were also as same as the previous study to investigate the behavior of the change in individuals with CNSLBP compared to the acute patients that had been taken as reference. The results in this study were therefore can be concluded such that the responsiveness in individuals with CNSLBP was lower than patients with acute LBP in the clinical outcomes such as pain and disability level.

One of the limitations in this study is the responsiveness analyses, which was internal responsiveness. The external responsiveness was not studied since another relevant outcome measure was needed for correlation. However, the individuals with CNSLBP had many clinical aspects which were difficult to determine, requiring another relevant outcome to cover all. Another consideration was the time interval. The future study should take longer period for the responsiveness analysis to see greater change representing larger responsiveness.

Conclusion

This study investigated the responsiveness of the clinical outcomes used to measure the changes in individuals with CNSLBP at 2 weeks after the beginning of interventions.

The most responsive parameter in this study was pain as presented with the highest values in ES and standardized response mean. While the functional capacity tests were less responsive than pain, the longer duration of physical therapy intervention aiming to promote functional capacity is needed which is also suggested for further investigation.

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Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

The preparation of the paper along with the literature review and data analysis was carried out by Prasert Sakulsriprasert.

Roongtiwa Vachalathiti helped in preparation of the paper, research design planning, results validation and research team training. Pathaimas Kingcha helped in data collection, literature review and team coordination.

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Thai dance exercises benefited functional mobility and fall rates among community-dwelling older individuals

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Background: With dramatic increase in the number of older individuals, special efforts have been made to promote the levels of independence and reduce fall rates among these individuals.
Objective: To investigate the effects of Thai dance exercises over 6 weeks on functional mobility and fall rates in community-dwelling older individuals.
Methods: Sixty-one community-dwelling older adults were interviewed and assessed for their demographics and fall data during 6 months prior to participation in the study. Then they completed the quasi-experimental Thai dance exercise program for 50 minutes/day, 3 days/week over 6 weeks. Their functional mobility relating to levels of independence and safety were assessed prior to training, at 3-week and 6-week training. After completing the program at 6 weeks, participants were prospectively monitored for fall data over 6 months.

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Results: Participants improved their functional mobility significantly after 3- and 6-week training ($p < 0.01$). The number of faller individuals obviously decreased from 35% ($n = 21$) prior to training to only 8% ($n = 5$) after training ($p < 0.01$).
Conclusion: The current findings further extend benefits of Thai dance as an alternative musical exercise program to promote levels of independence and safety among community-dwelling older adults.

Keywords: Older adult; fall; balance; walking; cultural dance.

Introduction

Advancing age commonly accompanies many system declines that affect several contributors to independence and risk of falls among older individuals, including a safe and efficient ambulatory status, good static and dynamic balance, adequate lower extremity muscle strength, and good functional endurance.[1,2] Therefore, special efforts have been made to promote levels of independence and reduce fall rates among these individuals, particularly in the current era, whereby the number of older adults has obviously increased.

Many exercise programs have been reported for their effectiveness in promoting the physical performance of older individuals.[1,3,4] Among existing programs, musical and dance exercise programs have been reported to enhance recruiting and retaining of older individuals in the exercise programs.[5] However, the existing reports on cultural dance programs — Brazilian, Turkish and Greek dances — have their own characteristics and varying options based on the country of origin that are suitable for their populations.[6,7] Thus, they may be difficult to be applied for Thai older individuals, i.e., need special and long training duration to be familiarized in the training programs.

By contrast, Thai dance exercise is well known and widely used by Thai people. The program is characterized by smooth, gentle, and coordinated movements involving the whole body[8] that might be particularly challenging for the important contributors to the independence, community participation, and safety of older individuals such as balance and walking ability, lower limb muscle strength, and functional endurance.[2,5] However, there are few studies reporting benefits of Thai dance exercises, and only in female individuals without consideration of all variables needed for being independent, along with fall rates of the participants.[9,10] Further exploration on the effects of Thai dance exercises in both male and female individuals on variables necessary for being independent and fall rates would extend the clinical implication of the program for older adults. Therefore, this study compared the effects of Thai dance exercises over 3 and 6 weeks on the functional mobility necessary for being independent, including the timed up and go test (TUG), five times sit-to-stand test (FTSST), 10-meter walk test (10 MWT), and 6-minute walk test (6 MinWT)[2,5] and fall rates among community-dwelling older individuals.

Materials and Methods

Study design and population

This quasi-experimental study was conducted in community-dwelling older adults, aged 65 years and over, from several rural communities in Thailand, during November 2016 and September 2018. The eligible participants had to walk independently over at least 10 m without any assistive devices, and had not participated in a regular exercise program prior to being involved in the study. Older individuals who presented any signs and symptoms that might affect walking and the ability to participate in this study, such as unstable medical conditions, inflammation in the joints of the lower extremities (with a pain scale of more than 5 out of 10 on a visual analog scale), and having sequelae of neurological deficits, were excluded from the study.[2,11,12] The study protocol was approved by the local ethics committee (HE 602099) and eligible individuals signed a written informed consent before taking part in the study (clinical trial registration number NCT02919514).

Sample size calculation

The sample size was estimated from data of a pilot study ($n = 18$) for the primary outcome, the 10 MWT, with the effect size of 0.09 m/s, power of test at 80%, alpha level of 0.05, and a dropout rate of 20%. The findings indicated that the study required at least 55 participants.

Research protocols

Older adults who agreed to be involved in the study were screened and assessed for their eligibility according to the study criteria. Then, the eligible participants were interviewed and assessed for their demographics, including age, gender, body mass index, health status, and fall data over the previous six months prior to participation in the study, with data confirmation from their relatives and related events (if any), i.e., the date, time, place, circumstances, consequences, and treatment required. On the next day, participants were assessed for functional outcomes of the study. Then, they were trained using standard protocols of traditional Thai dance following video demonstration, and they subsequently became involved in a traditional Thai dance exercise program in their communities. Details of the training and testing protocols are as follows.

Thai dance exercise training

The program consisted of a warm-up session for 10 min, Thai dance exercises for 30 min, and a cool-down and muscle-stretching session for 10 min. The Thai dance exercises were performed with a video demonstration of the standard traditional Thai dance using eight songs, including the *Ngam sang duan, Chaw Thai, Ram ma si ma ram, Dong jan wan pen, Dok mai kong chat, Ying Thai jai ngam, Dong jan kwan fa*, and *Boo cha nak rop* songs. These songs required the participants to move and rotate their bodies while moving their arms upward, downward, and sideward alternately (Fig. 1). During these movements, both legs needed to step forward and backward with slight flexion of the knees on either a single or double limb support period according to the rhythm of the songs.[9] Participants were able to take a period of rest during the training, as needed. However, after being involved in the program, they were encouraged to increase training time or minimize resting periods, as they could. The participants were trained for 50 min/day, 3 days a week for 6 weeks; thus, there were 18 sessions in total. Data of

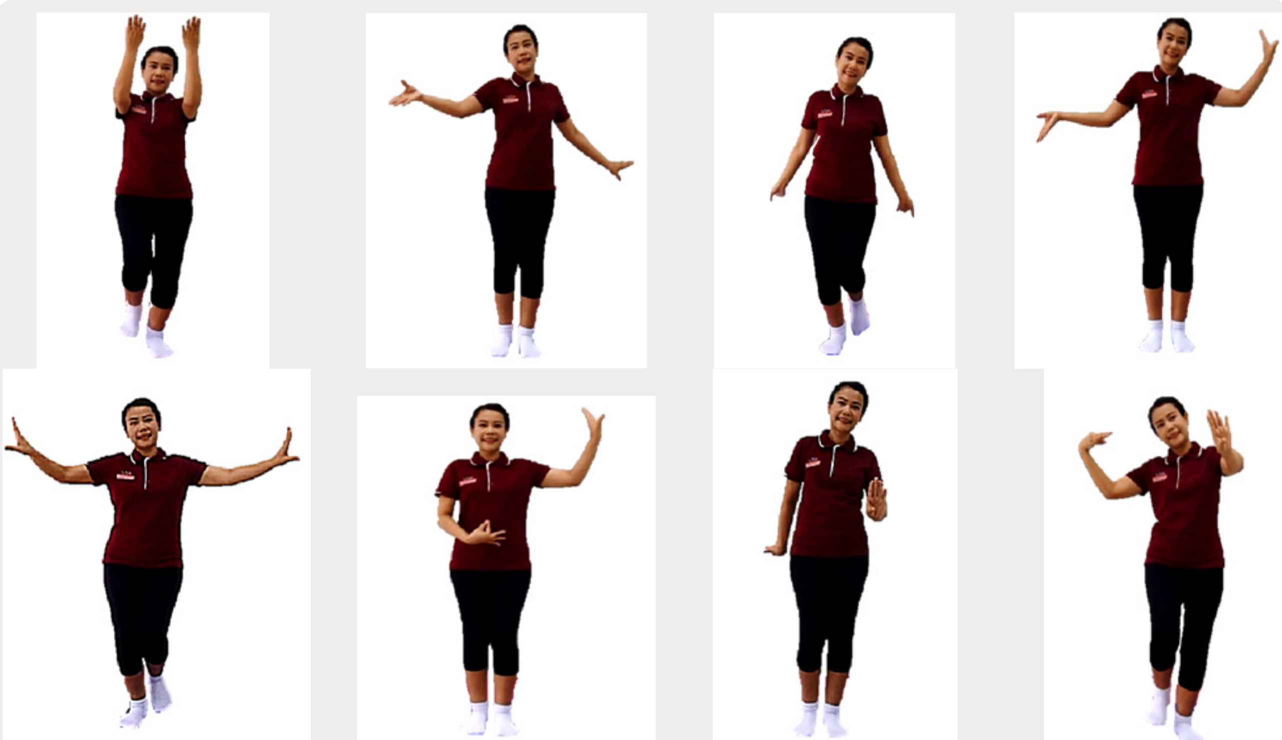

Fig. 1. Examples of Thai dance exercise maneuvers.

participants who participated in the training program for less than 15 sessions (80% of all training sessions) were excluded from the data analysis to clearly present the benefit of training over six weeks.[9]

Outcome measures

Participants were assessed for their functional mobility necessary for being independent, including the TUG, FTSST, 10 MWT, and 6 MinWT[2,5] in a random sequence. Prior to the assessments, a group of three raters were trained for the testing protocols and standard commands were used for the tests. Then they practiced using the tests in 10 pilot older individuals, and the data showed that these rates had excellent inter-rater reliability (intraclass correlation coefficients [ICCs] = 0.88–0.99). Subsequently, these raters were measured in the outcomes of the study three times, including prior to training (pre-test), after 3 weeks of training (intermediate test), and after 6 weeks of training (post-test). Then, participants were monthly monitored for fall data over 6 months using a fall diary and telephone interview. The details of each assessment are as follows.

10-meter walk test: The 10 MWT is a valid and reliable test (ICC = 0.88–0.97), and its outcomes reflect the overall quality of gait, and ambulatory and health status of older individuals.[13–17] The participants walked at a comfortable and fastest speed along a 10 m walkway, and the time used over the 4 m in the middle of the walkway was recorded to minimize acceleration and deceleration effects.[12–14] Then, the findings were converted to a walking speed in meters/second (m/s).

Timed up and go test: The TUG is an excellent reliability test (ICC = 0.97–0.99) that is widely used to measure the dynamic balance control, mobility and fall risk of older adults.[18,19] The participants were instructed to rise from an armrest chair, walk around a traffic cone that was placed 3 m ahead of the front edge of the chair, and return to sit down on the chair in the fastest and safe manner. The test recorded the time from the command "go" until the participant's back was against the backrest of the chair.[2,12,19]

Five times sit-to-stand test: The FTSST is a valid and excellent reliability test (ICC = 0.97–0.99) where the outcomes reflect functional lower extremity muscle strength and dynamic balance control while changing postures from sitting to standing.[20–23] Participants performed five repetitive chair-rise cycles at the fastest speed and in a safe manner without using their arms. The test records the time in seconds from the command "go" until the participant's back touches the backrest of the chair after the fifth repetition.[2,12,22]

6-minute walk test: The 6 MinWT is an excellent reliability test (ICC = 0.95) that is commonly used to represent functional endurance in community-dwelling older individuals.[24] The test records the longest distance walked along a rectangular walkway (96 m) in 6 min. Every minute during the test, participants were informed of the time remaining and encouraged to continue walking as soon as they could. Then, the total distance covered after 6 min was recorded.[12,25]

The 6 MinWT was performed over one trial, and the 10 MWT, TUG, and FTSST were assessed over three trials, where the average findings were used for data analysis. During the tests, an assessor was beside or walked alongside the participants without interruption to ensure the participants' safety and the accuracy of the outcomes. The participants wore a proper size of sandal sport shoes that were prepared by the researchers, and they were given a practice session so they could familiarize themselves with the shoes. Participants were able to take a period of rest during the study and the tests as needed.

Fall surveillance: After completing the program over six weeks, participants received a fall diary to record fall data and related events daily over six months. A researcher phoned them every month to gather the fall data of the month. Each fall was confirmed by related events (including the date, time, place, circumstances, and consequences of the fall) and by their caregivers or relatives to promote the accuracy of the interviewed data. A fall was defined as "an unintentional event that resulted in a person coming to rest on the ground from an upright standing or walking activity as a result of neither a major intrinsic event (stroke or syncope) nor an extrinsic cause".[2,26]

Statistical analysis

Descriptive statistics were used to describe the demographics of the participants and findings of the study. The analysis of variance with repeated measures (repeated measures ANOVA) was used to analyze the different findings among the three measurement times of the participants. The Chi-square test was used to compare fall data during 6 months before and after training. The level of significant difference was set at p-value of < 0.05.

Results

Participants

Sixty-one participants, with an average age of 73 years and a normal body mass index, completed the study program (Fig. 2). Most were female ($n = 41$), and 21 participants (35%) experienced at least one fall during 6 months prior to participation in the study, where most ($n = 20$) had a single fall and one participant reported 2 falls (Table 1). The demographics between those who fell and did not fall showed no significant differences ($p > 0.05$). Other baseline demographics are presented in Table 1.

Outcomes of the study

After training, the participants showed significant improvements in all functional outcomes at week 3 and week 6 ($p < 0.01$). The improvement was particularly demonstrated for the FTSST where the outcomes after the training differed significantly from both the pre-test and intermediate-test ($p < 0.01$; Table 2). Furthermore, the number of those who fell was significantly reduced as

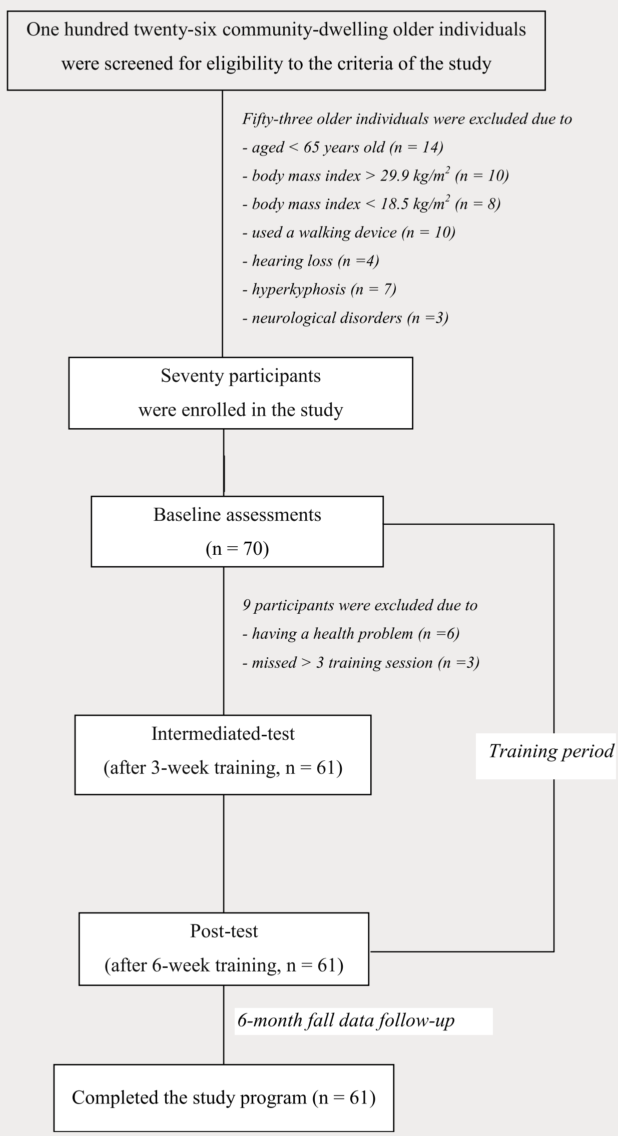

Fig. 2. Participation flowchart.

Table 1. Baseline demographics and fall data of the participants ($N = 61$).

Variable	Baseline data[c]	Post-training[d]
Age[a] (years)	72.9 ± 5.7	
Weight[a] (kg)	57.1 ± 7.7	
Height[a] (cm)	155.1 ± 7.2	
Body mass index[a] (kg/m^2)	23.7 ± 2.9	
Number of medications[b]		
Less than 4 types	51 (84)	
At least 4 types	10 (16)	
Gender[b]		
Female	41 (67)	
Male	20 (33)	
Fall data[b*]		
No fall	40 (65)	56 (92)
Single fall	20 (33)	4 (6)
Multiple falls	1 (2)	1 (2)

Notes: [a]The data are presented using mean ± standard deviation (95% confidence intervals), [b]these variables were presented using number (%), [c]the fall data were interviewed retrospectively over 6 months, [d]the fall data were prospectively gathered over 6 months, *Chi-square test indicated significant difference with p-value < 0.01.

compared to the data prior to training ($p < 0.01$), where only five participants (8%) experienced falls during the 6-month prospective follow-up period (4 participants reported a single fall, where 1 of them was the same person who fell prior to training, and another one participant experienced 2 falls, Table 1).

Discussion

Thai dance is a part of the traditional art and culture that is familiar to Thai people. However, little evidence supporting the benefit of Thai dance exercises in only female individuals was available without the consideration of fall data of the participants.[9,10] Thus, this study further assessed the effects of Thai dance exercises over 6 weeks on the functional mobility necessary for being independent, including the TUG, FTSST, 10 MWT and 6 MinWT, and fall rates over 6 months among community-dwelling older individuals. The findings indicated that participants improved all functional outcomes significantly since 3 weeks of training ($p < 0.01$), and their functional mobility at 6 weeks showed further improvement, but not significantly different from the data at 3 weeks, except the FTSST ($p < 0.01$, Table 2). Moreover, the number of faller individuals was obviously reduced (from 21 participants [35%] prior to training to only five participants [8%] after training, $p < 0.01$).

Table 2. Functional mobility of the subjects at baseline, week 3, and week 6 ($N = 61$).

Variable	Baseline (week 0)	Intermediate-test (weeks 3)	Post-test (weeks 6)
Ten meter walk test (m/s)			
Preferred speed	1.12 ± 0.16 (1.08–1.16)	1.20 ± 0.15 (1.17–1.24)^{b**}	1.24 ± 0.16 (1.20–1.28)^{b**}
Fastest speed	1.38 ± 0.19 (1.32–1.42)	1.45 ± 0.22 (1.39–1.50)^{b**}	1.43 ± 0.19 (1.38–1.48)^{b*}
Timed up and go test (s)	10.29 ± 1.70 (9.86–10.73)	9.30 ± 1.23 (8.99–9.63)^{b**}	9.08 ± 1.10 (8.80–9.36)^{b**}
Five times sit-to-stand test (s)	13.52 ± 2.62 (12.85–14.19)	11.28 ± 2.48 (10.64–11.92)^{b**}	10.16 ± 1.94 (9.67–10.66)$^{b**, I**}$
Six minute walk test (m)	332.2 ± 48.8 (319.7–344.7)	349.9 ± 47.7 (337.6–362.1)^{b**}	354.7 ± 46.6 (340.1–363.9)^{b**}

Notes: The data are presented using mean ± standard deviation (95% confidence intervals). *Indicates the level of significant difference with the p-value < 0.05, **p-value < 0.01. Superscripts indicate the measurement time with significant differences from the indicated period where ^{b} = baseline, and ^{I} = intermediate-test.

The significant improvement after training may relate to characteristics of the Thai dance program that required participants to step forward and backward repeatedly while raising and lowering the body over the extended and bending of a single and double limb support period of the lower extremities (Fig. 1).[8] The moderate rhythms of the songs also provided auditory cues to guide the participants to maintain their movement speed for over 30 min/day. Although some participants took a period of rest when they first became involved in the training program, they were encouraged to increase their participation duration to 30 min continuously as they could. Such training programs attributed both psychological and physical effects and are particularly challenging for important contributors to be independent in their daily living, such as lower limb muscle strength, balance control, walking ability, and functional endurance.[21,25] Therefore, the participants showed significant improvement in all functional outcomes of the study ($p < 0.01$, Table 2). However, the intermediate assessments at 3 weeks further suggested that the benefit of Thai dance exercise was demonstrated within a short period after training. The changes of these tests were also greater than the levels of clinical significance, i.e., greater than 0.05 m/s for the 10 MWT,[27] $> 9\%$ changes for the TUG,[28] and 20 m for the 6 MinWT.[27] Therefore, the findings further extend the benefit of Thai dance exercise program over 3 and 6 weeks on functional ability of older adults necessary for being independent.

Of all the functional measures, an improvement was obviously found for the FTSST, where the improvement after 6 weeks was significantly different from their baseline ability (3.36 s) and intermediate assessments ($p < 0.01$, Table 2). This improvement was greater than that used to determine clinical significance (2.3 s).[29] The findings may reflect effects of the training program that required the participants to bend the knees always while moving their arms and body forward, backward, and sideward. Repetitive practice in such tasks may particularly challenge the lower limb muscle strength and dynamic balance ability that is necessary to complete the FTSST.[20,30] The improvement of FTSST is important as it is widely used to predict lower limb disability and independent living among older individuals.[20,22,31,32]

The improvement in the outcomes of these tests is also important for fall prevention among older individuals.[2,19,21,25] Thus, the number of participants who fell was significantly reduced from 21 participants to only 5 participants (Table 1). Nonetheless, the fall data from retrospective and prospective follow-up may contain some sources of bias, e.g., recalling bias and Hawthorne effects that may affect data comparisons in the findings. In addition, fall events can occur due to various extrinsic causes, such as environmental hazards,[2,19] that need to be taken into consideration for data interpretation.

The current findings were coherent with other cultural dances, such as Greek, Brazilian, and Turkish on the improvement of balance and physical ability.[6,7,33] However, the researchers[6] recommend that these dances are specific to the country of origin, and thereby may not allow generalization. The current findings further extend the benefit of Thai dance exercise for ability of being independent and on fall rates in participants who had good adherence to the Thai dance program (at least 80% of the total session (15 sessions).[34,35] The intermediate assessments also suggest the benefit over a short training duration (3 weeks). Thus, the findings further confirm the use of Thai dance exercise as an alternative training program familiar to Thai community-dwelling older individuals. However, the findings were derived from a quasi-experimental design without a control group to ensure time-frame effects due to daily activities. Nevertheless, a previous report using a similar program found no significant difference in the control group that did not receive any additional program over 6 weeks.[9] Moreover, with a single group study, the assessors were aware of the training program received by participants. However, the researchers attempted to minimize assessor-bias by using a group of excellent reliability raters (ICCs = 0.88–0.99). In addition, the findings did not analyze the data on recruiting and retaining rates, and did not measure the outcomes over a retention period. Therefore, a further study should apply a randomized controlled trial with the assessments of recruiting and retaining rates and a measurement during a retention period to thoroughly confirm the effects of Thai dance exercises.

Conclusion

Thai dance exercise program improved functional mobility of the participants after 3- and 6-week of training, as well as reduce the fall rates of older individuals. Hence, the present findings further confirm the use of a Thai dance exercise program, which is familiar to Thai individuals, as an alternative strategy to promote independence and safety among community-dwelling older adults.

Conflict of Interests

The authors declared no potential conflict of interests.

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Author Contributions

All authors were responsible for research conception and design, critical revision of the article for important intellectual content, provision of study materials or patients. CK was additionally involved in the data acquisition, statistical analysis, and drafting of the manuscript. SA was also responsible for project management, funding application, and finalizing the manuscript.

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Association between lumbopelvic motion and muscle activation in patients with non-specific low back pain during forward bending task: A cross-sectional study

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Background: Evidence suggests patients with non-specific low back pain (NSLBP) have altered lumbar and pelvic movement patterns. These changes could be associated with altered patterns of muscle activation.
Objective: The study aimed to determine: (1) differences in the relative contributions and velocity of lumbar and pelvic movements between people with and without NSLBP, (2) the differences in lumbopelvic muscle activation patterns between people with and without NSLBP, and (3) the association between lumbar and pelvic movements and lumbopelvic muscle activation patterns.
Methods: Subjects (8 healthy individuals and 8 patients with NSLBP) performed 2 sets of 3 repetitions of active forward bending, while motion and muscle activity data were collected simultaneously. Data derived were lumbar and pelvic ranges of motion and velocity, and ipsilateral and contralateral lumbopelvic muscle activities (internal oblique/transverse abdominis (IO/TA), lumbar multifidus (LM), erector spinae (ES) and gluteus maximus (GM) muscles).
Results: Lumbar and pelvic motions showed trends, but exceeded 95% confidence minimal detectable difference (MDD_{95}), for greater pelvic motion ($p = 0.06$), less lumbar motion ($p = 0.23$) among patients with NSLBP. Significantly less activity was observed in the GM muscles bilaterally ($p < 0.05$) in the NSLBP group. A significant association ($r = -0.8$, $p = 0.02$) was found between ipsilateral ES muscle activity and

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lumbar motion, while moderate, but statistically non-significant associations, were found between GM muscle activity bilaterally and lumbar velocity (ipsilateral: $r = -0.6$, $p = 0.14$; contralateral: $r = -0.6$, $p = 0.16$) in the NSLBP group.
Conclusion: Findings indicated patients had greater pelvic contribution, but less lumbar contribution which was associated with less activation of the GM bilaterally.

Keywords: Lumbopelvic movement pattern; lumbopelvic muscle activation pattern; non-specific low back pain.

Introduction

Low back pain is a common health problem in many countries with high prevalence and recurrence rates.[1,2] Non-specific low back pain (NSLBP) is assigned when a recognizable or known specific pathology cannot be identified.[3] NSLBP is accountable for approximately 85% of low back pain.[4] Inappropriate management of low back pain can result in perpetuation and recurring low back episodes which can further cause financial burden for health care systems.[5–7]

Lack of understanding of underlying low back pain mechanism is one contributing factor responsible for such high recurrence rates.[8,9] Current research studies have demonstrated that patients with NSLBP have altered lumbar and pelvic movement patterns including relative contribution and velocity during an active forward bend.[10–14] One systematic review indicated altered lumbar and pelvic contribution among patients with NSLBP during the active forward bend.[11] This systematic review also demonstrated consistent findings for reduced lumbar velocity during this task.[11] Researchers interpreted slow lumbar velocity as an indicator of coping strategy to minimize excessive lumbar motion.[15–17] However, results from the lumbar segment alone may be insufficient to describe this phenomenon. Therefore, investigating the relative velocity of the lumbar spine and pelvis should support the interpretation in which patients with NSLBP use lumbar coping strategy to minimize excessive lumbar motion.

In addition, clinicians have suggested that altered lumbar and pelvic relative contribution and velocity among patients with NSLBP are associated with lumbopelvic muscle activation deficits.[18–21] Lumbopelvic muscles include the bilateral internal oblique/transverse abdominis (IO/TA), lumbar multifidus (LM), lumbar erector spinae (ES), and gluteus maximus (GM) muscles. They have been proposed as key contributors to provide dynamic stability during functional movement.[6,22–24] These functionally-impaired muscles should be responsible for changes in lumbar and pelvic movement patterns. However, the association between underlying lumbar and pelvic movement patterns and lumbopelvic muscle activation patterns during active forward bending among patients with NSLBP has not been systematically investigated.

Therefore, this study aimed to: (1) determine the difference in lumbar and pelvic movement patterns (relative contribution and velocity) between healthy individuals (CON) and patients with NSLBP (LBP), (2) determine the extent of differences in lumbopelvic muscle activation patterns (IO/TA, LM, ES, and GM) between CON and LBP, and (3) determine association between lumbar and pelvic movement patterns and lumbopelvic muscle activation patterns. We hypothesized that patients with NSLBP would have altered lumbar and pelvic relative contribution and velocity, as well as lumbopelvic muscle activation patterns. We also further hypothesized that associations would be found between lumbar and pelvic movement patterns and lumbopelvic muscle activation patterns. Enhanced knowledge resulting from this study would provide a significant step toward investigating underlying neuromuscular mechanisms, and the ability of exercise intervention to restore lumbar and pelvic movement patterns and lumbopelvic muscle activation patterns. The long term outcomes of this research could help improve physical therapy interventions specific to patients with NSLBP; thereby, optimizing clinical outcomes and preventing recurring symptoms.

Methods

Subjects

Eight patients with NSLBP between the ages of 21 and 65, and 8 age-, sex-, and BMI-matched healthy individuals were recruited from the University Physical Therapy Clinic. Additional inclusion criteria for patients with NSLBP included current episode of back pain less than three months causing them to seek medical or physical therapy intervention and not receiving any intervention involving the core stability in the last six months. Subjects were excluded if they presented clinical signs of systemic disease, definitive neurologic signs including weakness or numbness in the lower extremity, previous spinal surgery, osteoporosis, severe spinal stenosis, or inflammatory joint disease, pregnancy, any lower extremity condition that would potentially alter trunk movement in standing, vestibular dysfunction, extreme psychosocial involvement, and BMI greater than $30\,\mathrm{kg/m^2}$. This study constituted one part of the intervention with a pre-specified sample size; therefore, we did not perform sample size calculation. However, sample size requirements were derived for future replication of this study.

Instrumentation and measures

Electromagnetic tracking system (3D Guidance trakSTAR, Ascension Technology Corp., Vermont, USA) was used for motion data collection. Criteria-related validity with known quantity has been reported by the manufacturer. The coefficient of multiple determination demonstrated excellent ($R^2 = 0.98$) test–retest reliability of this system. Three sensors were attached to the subjects at the following landmarks: (1) the right femur (bony prominence of the right femoral lateral epicondyle); (2) the pelvis (over the spinous process of S2); and (3) the lumbar spine (over the spinous process of L1). These sensor placements were based upon recommendations of the International Society of Biomechanics.[25] This tracking system collected kinematic data at 100 Hz. Related work has demonstrated kinematics in conjunction with a dynamic systems approach that could be used to quantify movement patterns that represent clinically observed aberrant movement patterns.[14]

Electromyography (EMG) (TeleMyo 2400R G2, Noraxon Inc., Arizona, USA; common mode rejection ratio > 100 dB, input impedance > 100 MOhm, 500 gain) with pre-amplified bipolar electrodes (Kendall Medi-Trace 100, Kendall Inc.; Al/AgCl, disc-shaped, 1 cm diameter) was used to collect muscle activity from bilateral IO/TA, LM, ES, and GM. Skin was lightly abraded using abrasive paper and cleaned using cotton with alcohol to lower the skin impedance. IO/TA electrodes were placed at 2 cm medial to ASIS and on the inguinal line. LM electrodes were placed at 2 cm lateral to the L5 spinous process. ES electrodes were placed at 3 cm lateral to the L1 spinous process. GM electrodes were placed at midpoint between the greater trochanter and the last sacral vertebrae.[24] Electrodes were placed parallel to the muscle fibers with an inter-electrode distance of 2 cm. Analog EMG data included bandpass-filtered (10–1500 Hz), and differentially amplified to $+/-5$ V.

Procedures

This study employed a cross-sectional design. The institutional review board approval from the university was obtained (COA No. 2015/050.3004) before collecting data. Data were collected at the university laboratory (Motor Control and Neural Plasticity Laboratory) from August 2016 to October 2017. Each subject underwent the written informed consent process before providing data. Electromagnetic sensors and surface EMG electrodes were attached to the subjects' body landmarks. Subjects were instructed to perform a modified Sorensen test at submaximal level (15% of body weight) to derive bilateral LM and ES reference voluntary contraction (RVC). We used this submaximal level to avoid aggravating pain, which could change muscle activation patterns. In addition, subjects were asked to perform the maximal contraction of the hip extension in a prone position with 90° knee flexion position, and maximal abdominal hollowing in a crook lying position to derive RVC for GM and IO/TA, respectively.[26,27] These RVC were further used to normalize EMG data for each muscle group. Subjects were instructed to perform 2 sets of 3 consecutive repetitions of forward bending movement. The instruction was "please stand relaxed with equal weight on both legs, and then try to reach toward the floor as far as you can at your comfortable pace and return to starting position". Motion and EMG data were simultaneously recorded.

Data reduction

Data reduction was performed using a customary LabVIEW programming (National Instruments Corp.). Motion data were converted to segment angular rotations using Euler's angle in Cardan sequence (x, y, and z). Segment angular rotations included lumbopelvic motion (lumbar sensor in respect to femur sensor), lumbar motion (lumbar sensor in respect to pelvic sensor), and pelvic motion (pelvic sensor in respect to femur sensor). These data were filtered using a dual-pass Butterworth (2nd order low pass frequency at 5 Hz). Lumbar and pelvic ranges of motion and velocity were obtained. Maximal range of motion, time to maximal range of motion, maximal angular velocity, and time to maximal angular velocity for lumbar spine (MaxR_L, $\mathrm{TtoMaxR}_L$, MaxV_L, and $\mathrm{TtoMaxV}_L$), and pelvis (MaxR_P, $\mathrm{TtoMaxR}_P$, MaxV_P, and $\mathrm{TtoMaxV}_{\mathrm{LP}}$) for each repetition were derived. Averaged motion parameters across the first 3 and the last 3 repetitions were used to establish test–retest reliability and 95% confidence minimal detectable difference (MDD_{95}). All kinematics were analyzed and reported in the sagittal plane.

EMG data were filtered using independent component analysis to remove heart rate artifacts. Heart rate filtered EMG were further filtered using a band pass filter (2nd order Butterworth high pass at 20 Hz and low pass at 400 Hz) and a band stop filter (2nd order Butterworth at 50 Hz). These data were full-wave rectified and underwent data smoothing using root mean square (RMS) with a time constant of 50 ms. RVC data between 2 and 4 s was used to normalize muscle activity during the forward bending task. However, our preliminary data analysis demonstrated that pain location among patients with NSLBP could change muscle activation patterns; therefore, we separately analyzed muscle groups ipsilateral and contralateral to the pain location for the main analysis. Ipsilateral (I) and contralateral (C) peak EMG amplitudes for each muscle (IIO/TA, CIO/TA, ILM, CLM, IES, CES, IGM, and CGM) were derived. Similar to motion data, averaged EMG parameters across the first and last three repetitions were used to establish test–retest reliability and MDD_{95}.

Statistical analysis

Statistical analysis was performed using SPSS Software, Version 21.0 (IBM Corp., New York, USA). Intra-class correlation coefficients ($\mathrm{ICC}_{3,3}$) were used to establish test–retest reliability of motion and EMG parameters, and MDD_{95} were calculated. The normality test was performed using Kolmogorov–Smirnov goodness-of-fit test. When demographic data were normally distributed, the independent t-test was used. Otherwise, the Mann–Whitney's U test was used. The Chi-square test was used to compare sex. For motion data, a mixed design ANOVA with *post-hoc* pairwise comparisons (Bonferroni adjustment) was used for normally distributed data, while non-parametric statistics was used for non-normally distributed data. For EMG data, independent t-tests were used when data were normally distributed; otherwise, Mann– Whitney's U tests were used instead. To determine the association between motion and muscle activity, Pearson's correlations were used when data were normally distributed, while Spearman's rank tests were used when data were non-normally distributed. Confidence level (α) was set at 0.05.

Results

Demographic data (Table 1) demonstrated no significant difference ($p > 0.05$) in age, sex, BMI, as well as lumbar and pelvic ranges of motion and velocities between CON and LBP groups. Intraclass correlation coefficient ($\mathrm{ICC}_{3,3}$) demonstrated excellent test–retest reliability ($\mathrm{ICC}_{3,3}$ ranged between 0.90 and 1.00) of EMG and motion parameters, and a 95% confidence MDD_{95} was established (Appendix).

Table 2 demonstrates results from mixed ANOVA with *post-hoc* pairwise comparisons. Results demonstrated a trend in the interaction effect of Group * Segment ($p = 0.05$), and a significant main effect of Segment ($p < 0.001$). *Post-hoc* comparisons showed that the LBP group exhibited a trend of greater MaxR_P compared with the CON group ($p = 0.06$). The MaxR_L was similar between the LBP and CON groups ($p = 0.23$). No significant interaction effect was observed for velocity. The velocity result demonstrated only a significant main effect of Segment ($p = 0.03$). *Post-hoc* simple within-group comparisons demonstrated significantly greater MaxV_P compared with MaxV_L ($p = 0.03$) in the LBP group only.

Non-parametric Mann–Whitney's U tests for EMG data showed significant lower activation of both IGM and CGM in the LBP group compared with CON ($p = 0.02$ and 0.04, respectively); however, only median IGM exceeded MDD_{95} (Table 3).

Correlations between lumbar and pelvic movement patterns and muscle activation patterns were determined using Spearman's rank test (Table 4).

Table 1. Demographic data.

Parameter	CON ($N = 8$)	LBP ($N = 8$)	p-value
Age ± SD (years)	27.7 ± 5.0	29.4 ± 5.2	0.54
Sex (% female)	42.9	42.9	1.00
BMI (kg/m^2)	22.1 ± 2.3	24.5 ± 2.2	0.08
$MaxR_{LP}$ ± SD (degrees)	98.9 ± 14.4	104.4 ± 12.1	0.42
$MaxV_{LP}$ ± SD (degrees/sec)	102.2 ± 29.0	98.8 ± 44.4	0.86
NPRS (out of 10)	N/A	5.7 ± 1.9	N/A
ODI (percent)	N/A	19.7 ± 7.5	N/A

Notes: CON = Healthy controls, LBP = Low back pain, SD = Standard deviation, BMI = Body mass index, $MaxR_{LP}$ = Lumbopelvic maximal range of motion, $MaxV_{LP}$ = Lumbopelvic maximal velocity, NPRS = Numeric pain rating scale, ODI = Oswestry disability index, N/A = Not applicable.

Correlation results in the LBP group demonstrated that a strongly significant negative association ($r = -0.8$, $p = 0.02$ was found between IES and $MaxR_L$.

When analyzing the CON group (Table 4), strongly significant negative associations were found between IIO/TA and $MaxV_L$ ($r = -0.8$, $p = 0.02$), ILM and $MaxV_L$ ($r = -1.0$, $p < 0.001$), IGM and $MaxV_L$ ($r = -0.8$, $p = 0.02$), and CGM and $MaxV_L$ ($r = -0.8$, $p = 0.01$).

Discussion

Demographic data indicated both groups were comparable, and performed the same task. Test–retest reliability of EMG and motion parameters were excellent indicating that subjects consistently performed the active forward bend task and our measurement was reliable, allowing us to confidently interpret our data as a true difference between group comparisons when difference exceeds MDD_{95}.[28]

We have simultaneously collected lumbar and pelvic motion and lumbopelvic muscle activity data in this study. This allows us to comprehensively explain altered lumbar and pelvic relative contributions, and changes in lumbopelvic muscle activation responsible for those changes in relative contribution during an active forward bend.

Although healthy individuals and patients with NSLBP performed the same active forward bend task, we found that patients with NSLBP tended to use lower lumbar contribution, but significantly greater pelvic contribution, than those among healthy individuals. Our motion results were consistent with several lumbar and pelvic motion studies in which they found similar changes in lumbar and pelvic contributions.[10–14] In addition, within-group comparisons suggested that patients with NSLBP obviously used pelvic dominate movement patterns, while healthy individuals used shared patterns between lumbar spine and pelvis during active forward bend.[14]

To our knowledge, no study has investigated the relative velocity of the lumbar spine and pelvis during the active forward bend. Our findings suggested that patients with NSLBP may attempt to compensate slow lumbar motion by increased pelvic velocity. In other words, slower lumbar motion among patients with NSLBP may indicate that they attempted to minimize lumbar motion to prevent excessive lumbar motion.[15–17]

Findings in muscle activation patterns suggested that patients with NSLBP had lower muscle activation of the bilateral GM muscles. Our results were consistent with one related study in which they found that GM muscles were more fatigable among patients with NSLBP.[23] Lower bilateral GM muscle activation could alter body mechanics during trunk flexion and extension, particularly load transfer in the lumbar spine.[23] This could further lead to stress on the lumbar region; thereby, developing a low back symptom.[17,29]

Patients with NSLBP demonstrated coping strategy by increased ipsilateral ES muscle activation to minimize this shear force on the lumbar spine,[17] which was supported by a strong negative association between the ipsilateral ES muscle and maximal lumbar range of motion.

Lumbar maximal velocity representing trunk neuromuscular control on the lumbar motion[14] seemed to be modulated by all lumbopelvic muscles

Table 2. Interaction and main effects from mixed ANOVAs, as well as between groups and within group post-hoc pairwise comparisons.

Kinematics	Mixed ANOVA		F value	p-value	η^2		Parameters	CON (Mean ± SD)	LBP (Mean ± SD)	Between-group mean diff	MDD_{95}	p-value
ROM	Interaction effect	Group × Segment	4.44	0.05	0.24	Post-hoc comparison	$MaxR_L$ (degrees)	42.5 ± 11.3	36.0 ± 9.6	6.53*	2.29	0.23
							$MaxR_P$ (degrees)	56.4 ± 12.6	68.4 ± 10.5	−12.03*	4.22	0.06
	Main effect	Group	0.68	0.42	0.05		Within-group mean diff	−13.9	−32.4			
		Segment	27.70	< 0.001	0.66		p-value	0.04	< 0.001			
Velocity	Interaction effect	Group × Segment	0.74	0.40	0.05	Post-hoc comparison	$MaxV_L$ (degrees/second)	58.1 ± 13.0	53.3 ± 23.4	4.70	7.10	0.63
							$MaxV_P$ (degrees/second)	67.2 ± 24.8	72.3 ± 34.7	−5.10	13.23	0.74
	Main effect	Group	< 0.001	0.99	< 0.001		Within-group mean diff	−9.1	−18.9			
		Segment	6.02	0.03	0.30		p-value	0.28	0.03			

Notes: $MaxR_L$ = Lumbar maximal range of motion, $MaxR_P$ = Pelvic maximal range of motion, $MaxV_L$ = Lumbar maximal velocity, $MaxV_P$ = Pelvic maximal velocity, CON = Healthy controls, LBP = Low back pain, SD = Standard deviation, Mean diff = Mean difference, MDD_{95} = 95% confidence minimal detectable difference. $*$ = Exceed 95% confidence minimal detectable difference.

Table 3. Lumbopelvic muscle activation pattern comparison between groups.

Muscle	CON Median [ICR]	LBP Median [ICR]	Median diff	MDD_{95}	p-value
IIO/TA	54.4 [14.5, 85.6]	21.5 [15.4, 68.6]	32.9	34.9	0.65
CIO/TA	53.8 [7.0, 76.4]	24.5 [14.0, 72.6]	29.3	29.4	0.96
ILM	77.6 [27.8, 179.1]	24.6 [20.0, 83.2]	53.0	274.7	0.33
CLM	51.6 [27.3, 84.5]	27.1 [24.1, 46.6]	24.5	31.9	0.44
IES	54.2 [37.6, 367.6]	62.2 [18.6, 265.1]	−8.0	80.2	0.57
CES	175.3 [31.9, 316.4]	54.4 [22.2, 139.0]	121.0	95.9	0.51
IGM	59.6 [31.0, 107.3]	21.3 [12.2, 37.7]	38.4*	21.1	0.02
CGM	39.6 [30.7, 81.6]	18.6 [13.8, 30.6]	21.0	76.6	0.04

Notes: I = Ipsilateral, C = Contralateral, IO/TA = Internal oblique/transverse abdominis, LM = Lumbar multifidus, ES = Erector spinae, GM = Gluteus maximus, CON = Healthy controls, LBP = Low back pain, SD = Standard deviation, ICR = Interquartile range, Mean diff = Mean difference, Median diff = Median difference, MDD_{95} = 95% confidence minimal detectable difference. $*$ = Exceed 95% confidence minimal detectable difference.

Table 4. Correlation between lumbopelvic movement pattern (spatial and temporal) and lumbopelvic muscle activation patterns based on all subjects.

		Spatial parameter				Temporal parameter			
Group	Muscle	$MaxR_L$	$MaxV_L$	$MaxR_P$	$MaxV_P$	$TtoMaxR_L$	$TtoMaxR_P$	$TtoMaxV_L$	$TtoMaxV_P$
LBP	IIO/TA	0.3	0.1	−0.3	0.1	0.2	0.2	0.2	0.1
	CIO/TA	−0.3	0.1	0.2	0.4	−0.3	−0.1	−0.1	−0.2
	ILM	0	−0.2	−0.5	−0.2	0.3	0.1	0	0.2
	CLM	−0.6*	−0.1	0.2	0.2	−0.4	−0.3	−0.4	−0.2
	IES	−0.8**	−0.1	0.1	0.4	−0.3	−0.2	−0.2	−0.1
	CES	0.3	0.1	−0.4	−0.2	0.1	−0.2	−0.3	0
	IGM	−0.1	−0.6*	0	−0.4	0.5*	0.6*	0.4	0.6
	CGM	−0.4	−0.6*	−0.5	−0.4	0.2	0	−0.1	0.2
CON	IIO/TA	−0.2	−0.8**	0.1	0	0.1	−0.1	−0.1	0
	CIO/TA	−0.4	−0.5*	0	0	0	−0.1	−0.1	−0.2
	ILM	0.1	−1.0**	0.1	−0.1	0.1	0	−0.2	0.1
	CLM	−0.2	−0.6*	0.2	0.3	−0.2	−0.4	−0.5*	−0.2
	IES	−0.2	−0.5*	0.3	0.2	−0.3	−0.5*	−0.4	0
	CES	−0.4	−0.7*	0	0.1	−0.1	−0.2	−0.3	0
	IGM	0.1	−0.8**	0	−0.1	0	−0.2	−0.3	0.3
	CGM	0.4	−0.8**	0	−0.2	0.3	0.1	−0.1	0.4

Notes: LBP = Low back pain group, CON = Healthy control group, I = Ipsilateral, C =“eqno–“rm ″ Contralateral, IO/TA = Internal oblique/transverse abdominis, LM = Lumbar multifidus, ES = Erector spinae, GM = Gluteus maximus, L = Lumbar spine, P = Pelvis, MaxR = Maximal range of motion, TtoMaxR = Time to maximal range of motion, MaxV = Maximal velocity, TtoMaxV = Time to maximal velocity.

Notes: Statistical analysis was performed using Spearman' rank test. ∗∗ = Strong association ($r > 0.70$) with statistical significance ($p < 0.05$). ∗ = Moderate association (r between 0.50 and 0.69), but not statistical significance ($p > 0.05$).

evident by a moderate to strong negative association between each lumbopelvic muscle and maximal lumbar velocity among healthy individuals. Notably, the bilateral GM muscles might be key muscles that need to be considered when treating patients with NSLBP. Based upon our findings, the bilateral GM muscles were strongly associated with lumbar maximal velocity among both patients with NSLBP and healthy individuals indicating the importance of these muscles to control lumbar spine motion. Inadequate activation of the bilateral GM muscles could cause altered lumbar spine control, as well as excessive hip motion. This would in turn increase stress on the lumbar spine leading to low back symptoms.[17,29]

Our findings suggest that clinicians should focus on the lumbar and pelvic contribution by restoring lumbopelvic muscle activation patterns among patients with NSLBP. Specifically, interventions should be designed to restore GM muscle activation to prevent excessive pelvic motion. Control of lumbar spine motion is also a key factor for managing patients with NSLBP. Restoring lumbar control would provide dynamic stability, and could be achieved by activating the bilateral lumbopelvic muscles. Therefore, excessive load on the lumbar spine would be minimized. This would also help to prevent recurring episodes of low back symptoms.

The findings of this study should be considered in light of the following limitations. This study was part of an intervention study that pre-specified a sample size of 16 (8 subjects per group). Therefore, findings associated between lumbar and pelvic motions and lumbopelvic muscle activation in our study tended to be under-powered. A minimum sample size of 24 would be required to detect significant associations using a calculated effect size, 80% power and confidence level of 0.05. Our study design, employed sub-maximal voluntary isometric contractions of the back muscles (the bilateral lumbar multifidus and ES muscles) to avoid pain exacerbation, while we used maximal contractions for other muscles, which would have limited the within-group comparisons. Therefore, we were unable to compare the level of activation across the lumbopelvic muscles. In addition, future studies may incorporate our findings to refine the intervention that addresses the lumbar and pelvic contributions, as well as muscle activation patterns. An intervention study would provide evidence to support whether changes in those motions and muscle activation would be effective in managing patients with NSLBP and minimize recurrence rate.

Our study concurrently investigated lumbar and pelvic motions and lumbopelvic muscle activation to enable the comprehensive analysis of underlying mechanisms during active forward bend. We found the difference in lumbar and pelvic contributions between patients with NSLBP and healthy individuals even though they were performing the same task. Patients with NSLBP had less activation of the bilateral GM muscle associated with lumbar maximal velocity. These findings suggested that contributions of the lumbar spine and pelvis, as well as GM muscle activation should be considered for managing patients with NSLBP.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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Author Contributions

PW substantially contributed to the concept, research design, data collection and analysis, paper preparation and edition. KS and SS have significantly contributed to data analysis and revising the paper. All authors read and approved the final paper.

Appendix A

Table A.1. Test–retest reliability, standard error of measurement, and 95% confidence minimal detectable difference for each parameter.

Variable	$ICC_{3,3}$	lower ICC	upper ICC	SEM	MDD_{95}
IIO/TA	1.00	0.99	1.00	0.13	0.35
CIO/TA	0.99	0.96	1.00	0.11	0.29
ILM	0.92	0.77	0.97	0.99	2.75
CLM	1.00	0.99	1.00	0.12	0.32
IES	0.91	0.74	0.97	0.29	0.80
CES	1.00	0.99	1.00	0.35	0.96
IGM	0.96	0.88	0.99	0.08	0.21
CGM	0.90	0.72	0.97	0.28	0.77
$MaxR_L$	0.99	0.98	1.00	0.83	2.29
$MaxR_P$	0.99	0.96	1.00	1.52	4.23
$MaxR_{LP}$	0.99	0.96	1.00	1.57	4.35
$TtoMaxR_L$	0.96	0.89	0.99	17.29	47.92
$TtoMaxR_P$	0.96	0.89	0.99	17.92	49.66
$TtoMaxR_{LP}$	0.97	0.92	0.99	16.61	46.03
$MaxV_L$	0.98	0.95	0.99	0.03	0.07
$MaxV_P$	0.97	0.93	0.99	0.05	0.13
$MaxV_{LP}$	0.99	0.96	1.00	0.05	0.12
$TtoMaxV_L$	0.97	0.91	0.99	8.68	24.06
$TtoMaxV_P$	0.96	0.87	0.99	14.73	40.83
$TtoMaxV_{LP}$	0.97	0.93	0.99	8.44	23.38

Notes: ICC = Intra-class correlation coefficient, SEM = Standard error of measurement, MDD_{95} = 95% confidence minimal detectable difference, I = Ipsilateral, C = Contralateral, IO/TA = Internal oblique/transverse abdominis, LM = Lumbar multifidus, ES = Erector spinae, GM = Gluteus maximus, L = Lumbar spine, P = Pelvis, LP = Lumbopelvic, MaxR = Maximal range of motion, TtoMaxR = Time to maximal range of motion, MaxV = Maximal velocity and TtoMaxV = Time to maximal velocity.

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Effect of home-based Tai Chi, Yoga or conventional balance exercise on functional balance and mobility among persons with idiopathic Parkinson's disease: An experimental study

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Background: Individuals with Parkinson's disease (PD) invariably experience functional decline in a number of motor and non-motor domains affecting posture, balance and gait. Numerous clinical studies have examined effects of various types of exercise on motor and non-motor problems. But still much gap remains in our understanding of various therapies and their effect on delaying or slowing the dopamine neuron degeneration. Recently, Tai Chi and Yoga both have gained popularity as complementary therapies, since both have components for mind and body control.
Objective: The aim of this study was to determine whether eight weeks of home-based Tai Chi or Yoga was more effective than regular balance exercises on functional balance and mobility.
Methods: Twenty-seven individuals with Idiopathic PD (Modified Hoehn and Yahr stages 2.5–3) were randomly assigned to either Tai Chi, Yoga or Conventional exercise group. All the participants were evaluated for Functional Balance and Mobility using Berg Balance Scale, Timed 10 m Walk test and Timed Up and Go test before and after eight weeks of training.

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Results: The results were analyzed using two-way mixed ANOVA which showed that there was a significant main effect for time as F (1, 24) = 74.18, $p = 0.000$, $\eta p^2 = 0.76$ for overall balance in Berg Balance Scale. There was also significant main effect of time on mobility overall as F(1, 24) = 77.78, $p = 0.000$, $\eta p^2 = 0.76$ in Timed up and Go test and F(1, 24) = 48.24, $p = 0.000$, $\eta p^2 = 0.67$ for 10 m Walk test. There was a significant interaction effect for time × group with F(2, 24) = 8.67, $p = 0.001$, $\eta p^2 = 0.420$ for balance. With respect to mobility, the values F(2, 24) = 5.92, $p = 0.008$, $\eta p^2 = 0.330$ in Timed Up and Go test and F(2, 24) = 10.40, $p = 0.001$, $\eta p^2 = 0.464$ in 10 m Walk test showed a significant interaction. But there was no significant main effect between the groups for both balance and mobility.
Conclusion: The findings of this study suggest that Tai Chi as well as Yoga are well adhered and are attractive options for a home-based setting. As any form of physical activity is considered beneficial for individuals with PD either Tai Chi, Yoga or conventional balance exercises could be used as therapeutic intervention to optimize balance and mobility. Further studies are necessary to understand the mind–body benefits of Tai Chi and Yoga either as multicomponent physical activities or as individual therapies in various stages of PD.

Keywords: Parkinson's disease; Tai Chi; yoga; balance; home-based setting.

Introduction

Parkinson's disease (PD) is a chronic progressive neurodegenerative disorder of insidious onset characterized by the presence of predominantly motor symptoms and a diversity of non-motor symptoms.[1] The Clinical Diagnostic Criteria proposed by UK Parkinson's Disease Society Brain Bank is Bradykinesia (slowness of initiation of voluntary movement with progressive reduction in speed and amplitude of repetitive actions); And at least one of the following: Muscular rigidity, 4–6 Hz resting tremor, Postural instability not caused by primary visual, vestibular, cerebellar, or proprioceptive dysfunction.[2]

PD is a universal disorder, with a crude incidence rate of 4.5–19 per 100,000 population per year and the total Daily Adjusted Life Years (DALY) globally in 2015 was 1.76 million (0.12%) and is expected to increase up to 2.01 million (0.13%) in 2030.[3] In a door-to-door survey of the Parsi community in Bombay, the crude prevalence estimates were 328 per 100,000.[4]

The basal ganglia, a key pathologic structure in PD, is involved in control of balance via the thalamic-cortical-spinal loops, the brainstem pedunculopontine nucleus and the reticulospinal system. The basal ganglia is involved in controlling the flexibility of postural tone, scaling up the magnitude of postural movements, selecting postural strategies for environmental context (central set), and automatizing postural responses and gait. Early in the disease, dopamine-sensitive bradykinesia and rigidity progressively affect balance and gait and later in the disease, dopamine insensitive-balance problems like impaired kinaesthesia, inflexible postural set, lack of automaticity, and executive dysfunction aggravate the balance and gait impairments.[5]

Cochrane's updated review in 2014 included 43 trials which highlight that a wide range of physiotherapy techniques have been tested to treat PD. Considering the small number of participants, the wide variety of physiotherapy interventions and the outcomes assessed, there is insufficient evidence to support the use of one approach of physiotherapy intervention over another for the treatment of PD.[6] There is a moderate evidence that physical activity and exercise will result in improvements in postural instability outcomes and to improve balance task performance in persons with mild to moderate PD.[7] A recent survey showed that Tai Chi and Yoga were the second most prevalent complimentary therapies utilized by individuals with PD and the perceived effectiveness of Yoga and Tai Chi were reported to be 73.8% and 60.9%, respectively.[8]

Tai Chi is a traditional Chinese martial art that involves slow and graceful movements that can improve postural balance, flexibility, and mood.[9] Tai Chi, as a mind–body exercise, consists of a series of dance-like movements linked in a continuous sequence, flowing slowly and smoothly from one movement to another that emphasizes weight transfer and movement of the body. The Tai Chi stresses weight shifting that trains the ankle strategy to effectively move the person's center of gravity toward the limits of stability, also by alternating between a narrow stance and a wide stance, the dorsiflexor and plantar flexors are strengthened.[10]

Previous studies had reported that mind–body exercises like Tai Chi showed improvement in motor and non-motor symptoms.[11] Tai Chi has reported to have promising improvement in mobility and balance, also it is considered safe and popular among individuals with PD at an early stage along with medications.[12] A meta-analysis concluded that improvement in balance was greater for Tai Chi plus medication than other exercise plus medication and medication alone.[13] But studies also have found that there was no significant difference in the gait velocity between Tai Chi and other exercises.[10,13]

Yoga is a popular mind-and-body practice which originated in ancient India. It concentrates on meditation, breathing, and postures. The control of posture practice in Yoga involves stretch and balance while maintaining a stable sitting or standing position. The reported benefits of Yoga training for healthy populations include improving muscle strength and endurance, muscle power, flexibility, balance and coordination, and health-related functions.[14] Yoga may also have psychosocial benefits through prevention and control of common health and emotional problems linked with aging.[15] A 12-week study on 13 participants with PD reported that there was a significant improvement in balance, strength, flexibility, and range of motion.[16] A pilot study reported that 3-month Yoga program significantly reduced bradykinesia and rigidity, and increased muscle strength and power in individuals with PD.[17]

Based on an analysis of dose for intervention prescription, it was found that for home-based exercise for people with Idiopathic Parkinson's disease, a minimum 150 min per week for at least six weeks improved balance-related activities.[18] Although India's ancient religious text brought forth the teachings and practice of Yoga, over time, it has been described as a way of uniting body and mind which is yielding therapeutic benefits. Based on the available literature, both therapies can be considered as an adjuvant for the patients with various neurological disorders. However, there is no recent literature evaluating the effects of home-based Tai Chi or Yoga on individuals with PD. So, this study focused on comparing the effects of home-based Tai Chi, Yoga or Conventional balance exercise program on balance and functional mobility among persons with idiopathic PD.

Methods

Participants

G-power software (version 3.1.9.2) was used to calculate the number of patients required for this study to achieve a significant level of 0.05, power of 0.95, and effect size of 0.73. To achieve the required power, 27 patients were included in this study. Inclusion criteria was (a) Subjects within age 60–85 years including both male and female. (b) Subjects who were in stage 2.5 (Mild bilateral disease with recovery on pull test) and 3 (Mild to moderate bilateral disease; some postural instability; physically independent) of Modified Hoehn and Yahr's Parkinson's stage. (c) Patients who were able to understand and follow the instructions. (d) Patients who were interested to participate and were not undergoing any other treatment other than medication.

Participants were excluded if they had (a) Severe co-morbidity influencing mobility or life-threatening disease. (b) Not interested to participate in any form of exercises. (c) Visual and vestibular disorder affecting balance. (d) History of osteoporosis, fracture or ankle instability, falls. (e) No care giver supervision or support.

All patients underwent a routine neurological assessment and were also assessed with Unified Parkinson's Disease Rating Scale (UPDRS) and sternal nudge test to classify the Modified Hoehn and Yahr's stage of PD in the "on" phase of medication by the Neurologist with a 25 years of experience and Movement disorder specialist at the Department of neurology, Kovai Medical Center and Hospital and then were referred to the Physiotherapist for the study. Twenty seven subjects who satisfied the selection criteria participated in this study and a written informed consent was obtained. These 27 patients were blinded to the groups and were randomly allocated by the alternate number method to the three groups. 9 patients were allocated to Group A: (Experimental

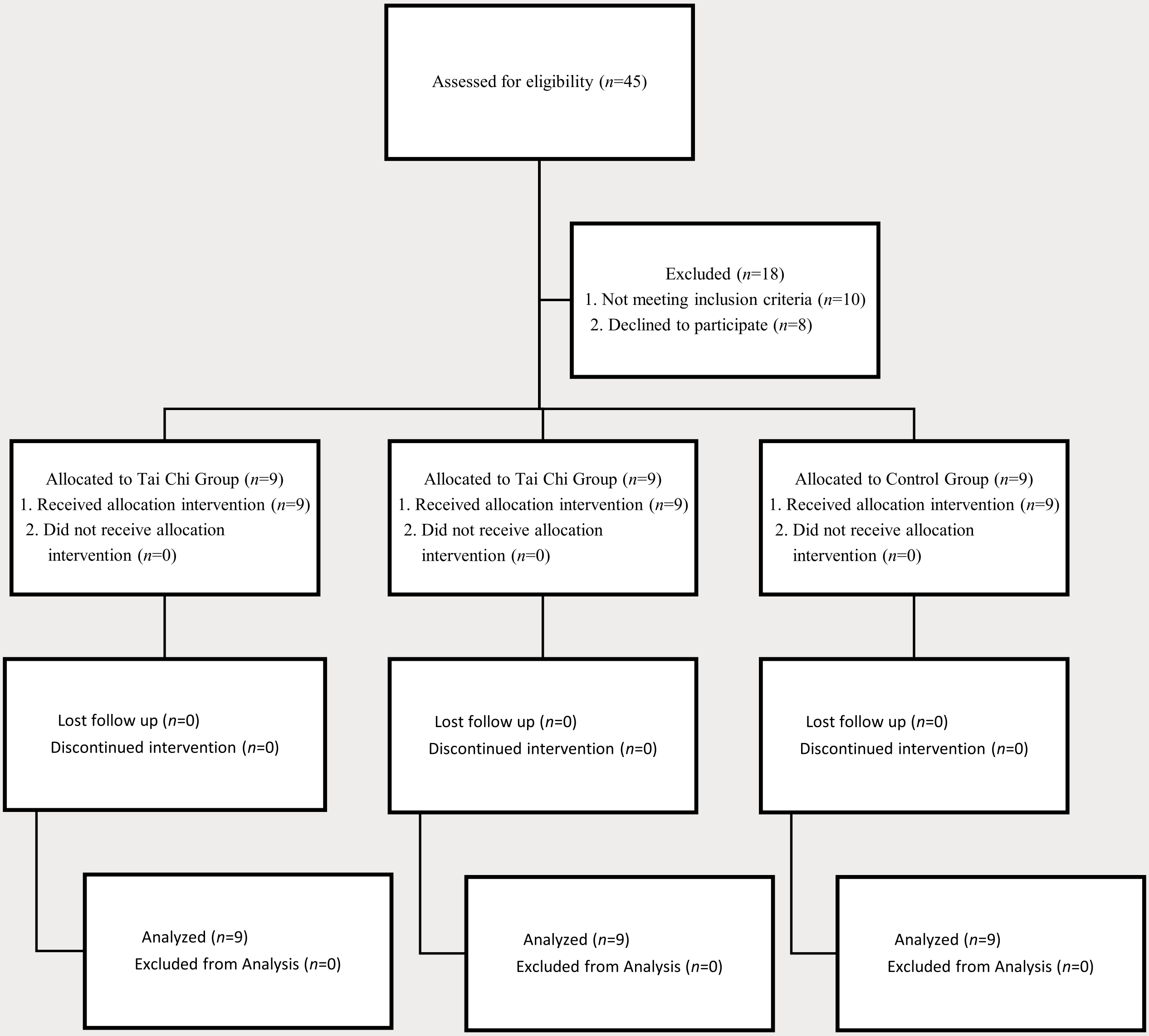

Fig. 1. Study flowchart.

Group I) who received Home-based Tai Chi exercise program, 9 patients were allocated to Group B: (Experimental Group II) who received Home-based Yoga exercise program and 9 Patients were allocated to Group C: (Control Group) who received Home-based General Balance exercises (Fig. 1).

Intervention

Tai Chi, Yoga and Conventional exercise programs were designed according to expert opinion and from available literature for a duration of eight weeks. Participants in Tai Chi group were taught exercises by the Physiotherapist under the guidance of the Tai Chi instructor with an experience of 10 years. Yoga was taught to the participants belonging to the Yoga group by the Physiotherapist who was certified in Yoga. General balance exercises were taught to the participants in the control group by the Physiotherapist. The first session was conducted at the Department of Physical Therapy, Kovai Medical Center and Hospital, India. The subjects were given an exercise pamphlet (supplement) and a record sheet was also provided to rate their adherence towards the exercise intervention and to mention about any difficulties they faced during the exercises which was collected after eight weeks. All the instructions and explanations to the participants were given in the presence of a family member who aided the home intervention. They were advised to do the exercises for a five days/week at a slow and comfortable pace and within the intensity ranges of 11–15 (light to somewhat hard) on the Borg Rating of Perceived Exertion Scale.[19] The subjects were advised to perform all the exercises on non-slippery floor and during the "on" phase of the medication that is within one to two hours after taking their medications preferably in the morning itself. The communication with the patient and the family member was established by means of a telephone call made every third day till the end of intervention. The patient and the family member were advised to contact at any time during the intervention in case of any difficulty.

Tai Chi exercise program

Each session of Tai Chi exercise program lasted for about 30–40 min and it included six exercise poses. Each pose (Fig. 2(a)) was repeated about five times initially and were gradually increased to 10 repetitions according to the subject comfort. All the exercises were performed in a slow pace with abdominal breathing pattern.

Yoga exercise program

Each session of the Yoga exercise program lasted 30–40 min and included six poses. Subjects were advised to breathe deeply and effortlessly with inhalation through nose and exhalation through mouth during the exercise. Each pose (Fig. 2(b)) was repeated five times initially and gradually increased to 10 repetitions according to the subject's preference.

Conventional balance exercise program

It included six conventional balance exercises which were standing back extensions, standing trunk rotations, backward walking, side-ways walking, tandem walking and single limb stance. Each exercise was repeated five times initially and gradually increased to 10 repetitions according to the subject's comfort. Subjects were advised to perform 10 steps in each repetition of Backward walking, Side-ways walking and Tandem walking. The exercise session lasted for about 40–45 min.

Outcome measures

All the outcome measures were assessed by the researcher who was not blinded. The balance was assessed by the Berg Balance Scale which comprises of 14 items on a five-point scale, ranging from 0–4.[20] "0" indicates the lowest level of function and "4" the highest level of function for a total score of 56. The functional mobility was assessed by the Timed 10-m Walk test and Timed Up and Go test. In Timed 10-m Walk test, the subjects

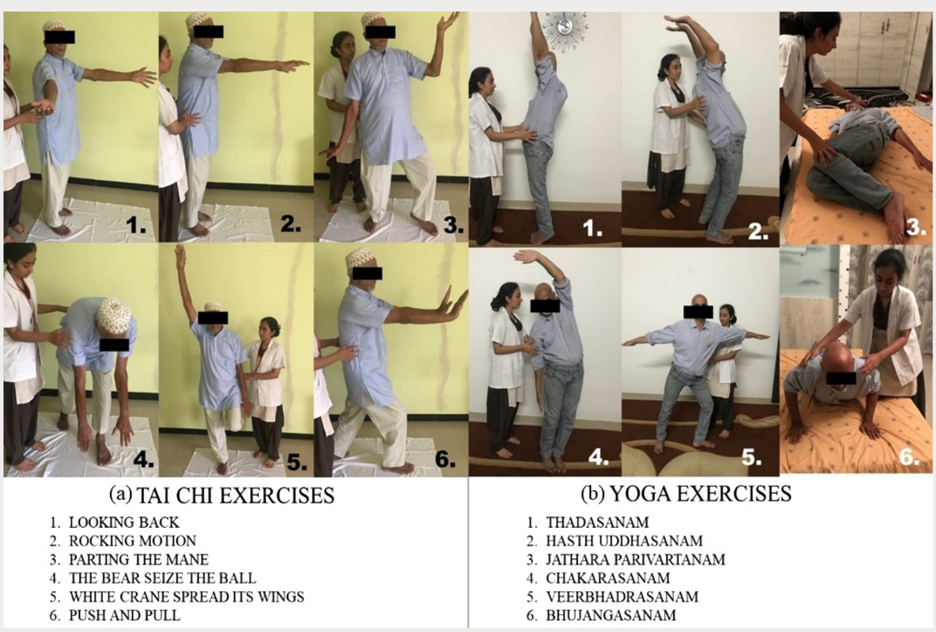

Fig. 2. Figure illustrating the exercises given to (a) Tai Chi Group and (b) Yoga Group.

were instructed to walk on a 10-meter long path and the time was measured in seconds for the intermediate 6 m (19.7 feet) to allow for acceleration and deceleration.[21] The Timed Up and Go test begins with the subject comfortably sitting on a standard chair with arm rest and then the subjects were instructed to stand up from the chair, walk to the line on the floor three meters away, turn around and walk back to the chair and sit down at a self-selected pace, the time duration in seconds for this was noted.[22] The outcome measures were obtained at baseline and after eight weeks as patients came for review to the hospital in the same setting.

Data Analyses

Data analysis was performed using SPSS Software (version 25). Mixed model (3 × 2) ANOVA was conducted that examined the effect of eight weeks Tai Chi, Yoga or Conventional Balance exercises on Balance and Mobility. Alpha level of significance was set at 0.05.

Results

Twenty-seven individuals with Idiopathic PD were assigned to either Tai Chi, Yoga or conventional exercise group who participated in this study. There was no difference in the baseline for age, UPDRS motor score, Modified Hoehn and Yahr's stages, sex, time with PD, Balance score, timed up and go time and 10 m walk time (Table 1) analyzed using Mixed Model ANOVA. The Two-way mixed ANOVA analysis (Table 2) for overall balance in Berg Balance Scale scores showed that there was a significant main effect for time as $F(1, 24) = 74.18$,

Table 1. Participant ($n = 27$) characteristics at baseline of the eight weeks Tai Chi, Yoga or General balance exercise study.

Groups	Age (in years)	Sex		Time with PD (years)	Motor subscale score (UPDRS)	Modified H&Y stage		BBS score	TUG time (s)	10 mWt time (s)
		M	F			2.5	3			
Tai Chi	72 ± 5.22	6	3	5.67 ± 2.33	17.22 ± 6.53	3	6	40.889 ± 6.94	16.328 ± 5.41	8.981 ± 2.33
Yoga	68.11 ± 4.23	6	3	6.2 ± 1.67	17.67 ± 6.30	3	6	44.222 ± 4.79	20.094 ± 13.18	10.497 ± 8.27
Control	70.89 ± 6.01	7	2	5.23 ± 3.12	20.22 ± 6.72	4	5	41.000 ± 9.19	16.203 ± 7.18	7.872 ± 2.98

Notes: PD- Parkinson's Disease; H&Y- Hoehn & Yahr Stage; BBS- Berg Balance Scale: TUG- Timed Up and Go; 10 mWt- 10 m Walk test.

Table 2. Pre-intervention values, Post-intervention values and p values assessed by Mixed Model ANOVA for Berg Balance Scale, Timed Up and Go and 10-m walk test.

Outcome measure	Treatment groups	Pre-test means with standard deviation	Post-test means with standard deviation	p = Main effects for time	p = Main effects for groups	p = Time and group interaction
Berg Balance Scale (score)	Tai Chi	40.889 ± 6.94	53.333 ± 1.32	0.000*	0.566	0.001*
	Yoga	44.222 ± 4.79	48.000 ± 4.69			
	Control	41.000 ± 9.19	47.333 ± 7.70			
Timed Up and Go (Seconds)	Tai Chi	16.328 ± 5.41	13.000 ± 4.4	0.000*	0.507	0.008*
	Yoga	20.094 ± 13.18	18.700 ± 13.54			
	Control	16.203 ± 7.18	14.822 ± 6.5			
10-m Walk test (Seconds)	Tai Chi	8.981 ± 2.33	7.023 ± 2.13	0.000*	0.053	0.001*
	Yoga	10.497 ± 8.27	9.894 ± 8.2			
	Control	7.872 ± 2.98	7.195 ± 2.79			

Note: *Level of significance $p \leq 0.05$.

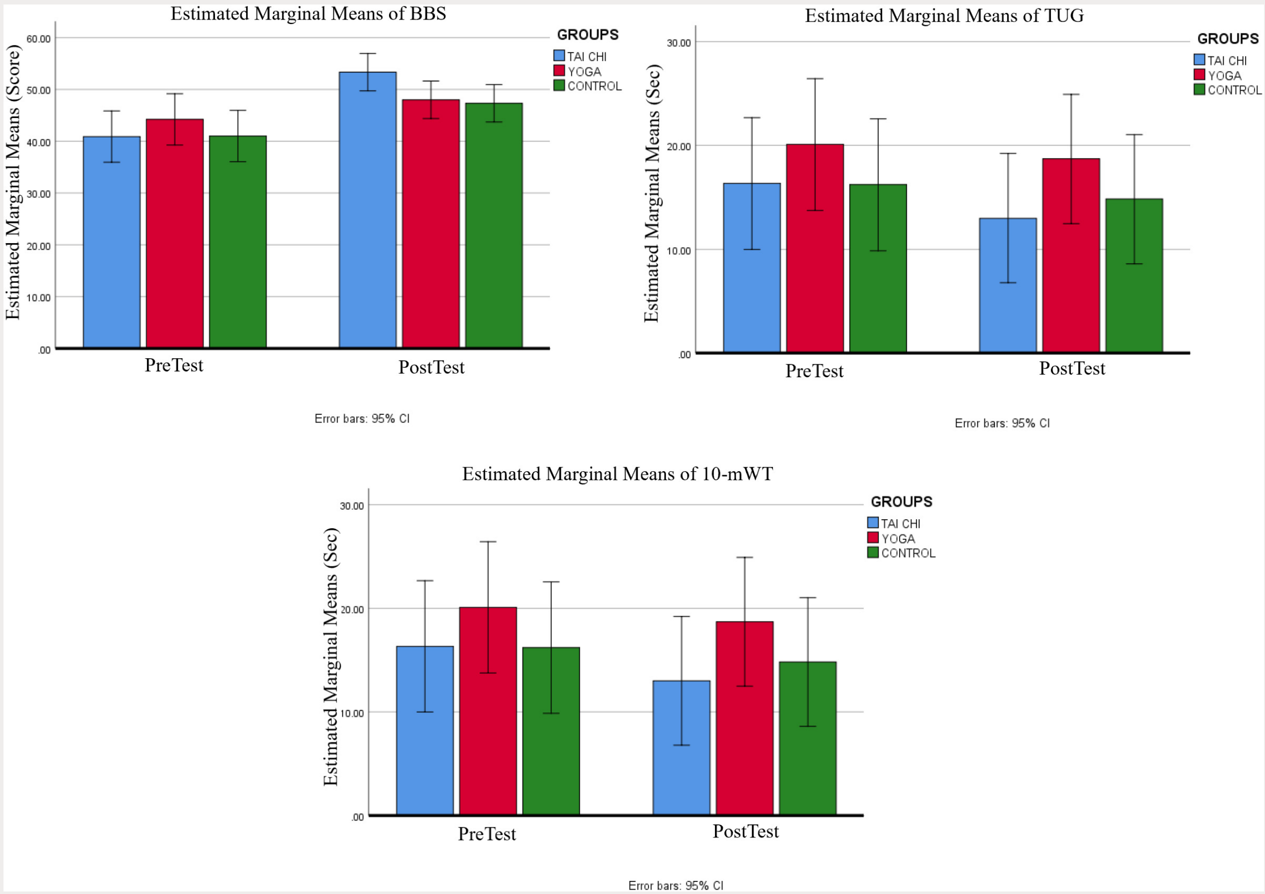

Fig. 3. Clustered bar graph depicting mean and standard deviation before and after eight weeks among three groups for Berg Balance Scale, Timed Up and Go and 10-m Walk test among participants.

$p = 0.000$, $\eta p^2 = 0.76$. There was also a significant main effect of time on mobility overall as $F(1, 24) = 77.78$, $p = 0.000$, $\eta p^2 = 0.76$ in Timed Up and Go test and $F(1, 24) = 48.24$, $p = 0.000$, $\eta p^2 = 0.67$ for 10 meter walk test.

There was a significant interaction effect for time × group with $F(2, 24) = 8.67$, $p = 0.001$, $\eta p^2 = 0.420$ for balance. With respect to mobility, the values $F(2, 24) = 5.92$, $p = 0.008$, $\eta p^2 = 0.330$ in Timed Up and Go test and $F(2, 24) = 10.40$, $p = 0.001$, $\eta p^2 = 0.464$ in 10 m Walk test showed a significant interaction.

There was no significant main effect for group with $F(2, 24) = 0.583$, $p = 0.566$, $\eta p^2 = 0.046$ on balance. Similarly, there was no significant main effect found between groups for mobility with $F(2, 24) = 0.699$, $p = 0.507$, $\eta p^2 = 0.055$ in Timed Up and Go test and $F(2, 24) = 0.667$, $p = 0.523$, $\eta p^2 = 0.053$ in 10 m Walk test. Further, *Post Hoc* analysis was not done as there was no significant group effect.

The mean Berg Balance score increased significantly by 26.414%, 8.193% and 14.339% in Tai Chi, Yoga or Conventional balance exercise group, respectively ($p < 0.05$). The mean Timed up and go time decreased significantly by 22.695%, 7.187% and 8.902% in Tai Chi, Yoga and Conventional balance exercise group, respectively ($p < 0.05$). The mean 10-m Walk Time decreased significantly by 24.469%, 5.914% and 8.986% in Tai Chi, Yoga and Conventional balance exercise group, respectively ($p < 0.05$) (Fig. 3).

All the subjects reported good adherence with a 92.78% compliance in Tai Chi group, 90.28% compliance in Yoga group and 71.94% compliance in control group. All the participant (100%) completed the program with 0% adverse events, injuries or falls.

Discussion

The home-based Tai Chi, Yoga or Conventional balance exercise program for eight weeks (40 sessions) showed no significant difference in balance and functional mobility between the three groups.

However, all the three groups showed statistically significant improvement after eight weeks in balance and functional mobility.

Xiaojia Ni *et al.*[13] in their meta-analysis reported mean difference (MD = 4.25, 95% CI 2.85–5.86) in the BBS score. In this study, the mean difference in the BBS score between Tai Chi and Yoga group was (MD = 5.33, 95% CI 0.86–11.52) and between Tai Chi and Control group was (MD = 6.00, 95% CI 0.19–12.19). Li *et al.*[10] found that Tai Chi training reduces balance impairment in patients with mild to moderate Parkinson's Disease. Choi *et al.*[9] found significant interaction effects in balance with 36 sessions of therapeutic Tai Chi given for 12 weeks. Later, Gao *et al.*[23] found that 26-week Tai Chi training improved more than control group on Berg Balance Scale, but not on Timed Up and Go Test. However, our results showed that there was statistically significant difference after eight weeks on both balance and mobility in all the three groups. However, there was no statistically significant difference in balance and mobility among the three groups.

In 2017, review by Song *et al.*[11] and in 2014, review by Yang *et al.*[24] found improvement in balance (Effect size = 0.544, $p < 0.0001$) and efficacy of balance (SMD-1.22, 95% CI; 0.80–1.65, $P < 0.00001$), respectively. Berg Balance Scale (BBS) is mostly used to assess balance function in Parkinson's disease. It has been previously reported that the Minimal Clinical Relevant Difference of the BBS is the improvement by five points.[25] In this study, a clinical improvement of 12.44 ± 6.19 points in the Tai Chi group was observed for balance after 40 sessions in eight weeks which is more than needed Minimal Clinical Relevant Difference.

The Tai Chi protocol stresses weight shifting and ankle sway to effectively move the person's center of gravity toward the limits of stability, alternating between a narrow stance and a wide stance to continually change the base of support, increasing support-leg standing time, engaging rotational trunk movements with upright posture, and performing heel-to-toe (forward) and toe-to-heel (backward) stepping movements to strengthen dorsiflexion and plantar flexion. Tai Chi also proposes improved flexibility and muscle strength.[10] Although these improvements indicate that Tai Chi would be effective in enhancing neuromuscular rehabilitation, the mechanisms behind the therapeutic change in participant's motor control and mobility remain less understood and needs future exploration.

The Tai Chi group showed an increase in mean BBS score by 26.414% while the Yoga group showed an increase in BBS score by only 8.193%. This could be explained in many ways. The first is Tai Chi that has many styles. In this study, Tai Chi was based on Qigong style, which was considered easy to follow and had different moves challenging balance.[26] Similarly, the Yoga group in this study had Thadasanam, Hastha Uddhanasanam, Chakrasanam, Veerabhadrasanam, Jathara Parivarthanam and Bhujangasanam Postures, which was mostly static and might not be sufficient in providing dynamic postural challenges. Second, different forms of Yoga and Tai Chi exist, varying in intensity as well as benefits. There is no stage specific standard Yoga protocol which could be tested against other complementary or mind–body therapies.[27] Third, Yoga could be considered as a spiritual intervention by the participants and Tai Chi as wellness intervention program. This study focused only on balance and mobility, not on non-motor symptoms like mood or depression which could have been influenced by Yoga. Cheung *et al.*[28] reported that Yoga is a safe, feasible and acceptable complimentary method for improving motor function in individuals with mild to moderate Parkinson's disease. However, longer duration or different set of Yoga patterns may be necessary for improvement in motor and non-motor functions in individuals with PD.

The protocol of the conventional balance exercise focused on the exercise that require the control of the body's center of mass while performing destabilizing movements and during reduction in base of support. Both static and the dynamic balance exercises were included in the conventional balance exercise program like single leg standing, standing back extension, standing trunk rotation, backward walking, heel walking and tandem walking. However, the conventional exercise group showed an increase in mean BBS score by 14.339% when compared to the Tai Chi group which showed an increase in mean BBS score by 26.414%. This could be because the exercises may not be sufficiently challenging for the subjects.

Regarding mobility component, Song *et al.*[11] in their 2017 review concluded that Tai Chi groups showed significant improvement in TUG Score when compared to the control groups, with a small effect size (Hedges's $g = -0.341$, 95% CI

–0.578 to –0.104, $p = 0.005$). However, Choi *et al.*[9] concluded there was no significant change in TUG scores in both Tai Chi and Control group after 12 weeks of training. On the other hand, the results of this study showed that there was statistically a significant difference in TUG scores in all the three groups. But there was no statistical significant differences in TUG scores after eight weeks among the three groups. Our finding in this study by the 10 m Walk test showed that there was a statistically significant difference in the scores after eight weeks of training in all the three groups, but no statistically significant difference was found among the three groups. The exercise protocol consisted of challenging movements in multiple direction which require more complex coordination that might have contributed to improved mobility.

Considering the difficulties in transport and cost, further follow up of participants were not carried out in this study. The participants needed moderate supervision during the initial period but however were able to perform all the exercise independently once they became confident.

Both Tai Chi and Yoga are increasingly gaining popularity as preferred Physical Activity. The "2018 Physical Activity Guidelines for Americans" recommends Tai Chi and Yoga as muscle strengthening exercise. This study found that though with eight weeks of training Tai Chi, Yoga or Conventional balance exercises did not show statistical significance among the three groups, there were beneficial effects on balance and mobility. Either Tai Chi or Yoga could be a good exercise strategy which individuals with PD can choose according to their preference and interest.

Conclusion

Both home-based Tai Chi or Yoga could be a potential therapy for improving Balance and Functional mobility for individuals with mild to moderate Idiopathic Parkinson's disease. These exercise programs are well adhered by the patient and can be an attractive option. Further, the effect of these therapies on various Hoehn and Yahr's stages of disease, duration and progression must be studied. Also, long term follow-up and large-scale studies are required to gain better insight and understanding.

Limitations

There were several limitations of this study that includes being mind and body exercises, the psychological aspect of Tai Chi and Yoga were not assessed. The researcher was not blinded to the groups of participants. The exercises were needed to be performed under supervision for an initial period. The entire study was performed in the "on" phase. A long-term follow-up was not done. Exercises for each group was established from previous studies, there was no stage specific exercise sets available.

Suggestions

Future research should focus on the effects of Tai Chi and Yoga therapy on non-motor symptoms of Parkinson's disease. Integrated exercise program for Balance can be established which can include either Tai Chi and Yoga together or separately. Future research should also focus on the effects of supervised versus unsupervised mode of exercise or group versus individualized therapy.

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Conflict of Interest

The authors have no conflict of interest.

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Author Contributions

AK and AB were involved in study conception and design. AK and AS performed data acquisition and test procedures. AK and AB performed the data analysis and/or interpretation. AK and AB wrote the first draft of this paper and all the authors revised it critically for important intellectual concept. All authors have given final approval of the version to be published.

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Intertester reliability of a movement impairment-based classification system for individuals with shoulder pain

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Background: Other than pathoanatomical diagnosis, physical therapy managements need the diagnosis of movement-related impairments for guiding treatment interventions. The classification system of the Movement System Impairment (MSI) has been adopted to label the musculoskeletal disorders in physical therapy practice. However, reliability study of this classification system in individuals with shoulder pain has not been reported in the literature.
Objective: This paper investigated the intertester reliability of the diagnosis based on the MSI classification system in individuals with shoulder pain.
Methods: The patients with shoulder pain, between the ages 18–60 years, were recruited if he or she had pain between 30 and 70 on the 100 mm visual analog scale for at least three months. The examiners who were two physical therapists with different clinical experiences received a standardized training program. They independently examined 45 patients in random order. Each patient was examined by both therapists on the same day. The standardized examination scheme based on the MSI approach was used. Patients were identified to subgroup syndromes according to scapular and humeral syndromes and also determining their subcategory syndromes. Six scapular subcategory syndromes included downward rotated, depressed, abducted, wing, internal rotated/anterior tilted, and elevated. Three humeral subcategory syndromes were anterior glide, superior glide, and medial rotated. More than one subgroup and subcategory of syndromes could be identified in each patient. The test results of each session were blinded to another therapist. The percentages of agreement and kappa statistic were determined.

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Results: The results showed that agreement levels in identifying subgroup syndromes was fair (71.11% agreement, kappa coefficient = 0.34) and classifying subcategories syndromes were poor to substantial (73.33–91.11% agreement, kappa coefficient = 0.20–0.66). The overall agreement and kappa value of the MSI classification of subcategory syndromes was poor (kappa coefficient = 0.11; 95% CI 0.05–0.18). The agreement level of subcategories for scapular depression and humeral superior glide syndromes was substantial. The scapular winging, depression, and downward rotation were the three syndromes that were most frequently identified by both the examiners.
Conclusion: The intertester reliability between therapists with different experience according to the MSI approach for shoulder pain classification was generally acceptable to poor due to the nature of the classification system. The standardized procedure and intensive training can be used for inculcating novice therapists with adequate level of intertester reliability of examination.

Keywords: Movement system impairment; reliability; shoulder pain classification; subacromial impingement syndrome.

Introduction

Shoulder pain is one of the most common and is ranked third among musculoskeletal complaints after back and neck pain.[1,2] Clinically, shoulder pain is varied in terms of symptom behaviors[3] and their pathoanatomical as well as the pathokinesiological lesions.[4,5] Evidences showed various alterations of movements during arm raising and lowering in patients with shoulder pain especially subacromial impingement syndrome (SIS).[6,7] Nowadays, the shoulder rehabilitation program focuses not only on treating the structures causing pain but correcting the abnormal alignments and movements leading to the injury.

The concept of the Movement System Impairment (MSI) has been proposed by Sahrmann[8] since 1980s and has been adopted among physical therapists. This approach is based on the kinesiopathological model which focuses on the identification of repetitive movements and sustained positions which are the primary cause of tissue injuries rather than the affected anatomical structures. According to the model, the movement system is composed of musculoskeletal, nervous, cardiopulmonary and endocrine systems interacting to produce normal biomechanics. However, specific directions of the repeated joint movement and sustained alignments are the inducers of soft tissue adaptations by changing tissue stiffness and extensibility associated with the loss of movement precision. Depending on the personal characteristics which are the individual modifiers, these factors lead to directional susceptible to joint movements and cause movement impairments. The repeated low-magnitude stress to the soft tissues then leads to tissue microtrauma and eventually progresses to tissue macrotrauma or pathology and leads to limitation of function.

Utilizing this approach, the therapist plays an important role in redesigning movements and managing the contributing factors of deviated movement causing pain. The diagnosis according to the MSI classification system provides the guidance for physical therapy intervention especially patient education regarding posture and movements, and specific therapeutic exercises. There was a case report of the MSI approach in patient with SIS illustrated its clinical utility in this condition.[9] The specific application of MSI classification system to the shoulder region is described by the characteristics of syndromes and sub-categories syndrome as shown in Appendix A.[8]

To apply a classification system in clinic, the psychometric properties are needed to be confirmed. The reliability studies of the MSI approach with various study procedures were available on low back pain[10–12] and knee pain.[13–15] The results showed good to excellent intertester reliability (kappa coefficients (K) = 0.61–0.71) for low back pain and substantial agreement between raters ($K = 0.66$–0.71) for knee pain. However, the reliability of using the MSI classification system to identify the movement impairments in patients with shoulder pain is still lacking. Therefore, the objective of this study was to investigate the intertester reliability of the diagnosis based on the MSI classification system in individuals with shoulder pain.

Materials and Methods

Study design

This study was an observational cross-sectional study investigating intertester reliability of the standardized MSI-based examination to classify individuals with shoulder pain.

Patients

The consecutive patient with shoulder pain aged between 18 and 60 years were recruited by convenience sampling method from the out-patient orthopedic clinic in a university hospital and a physical therapy center. Eligible patients had shoulder pain for at least three months and pain during movement rated between 30 and 70 on the 100 mm visual analog scale. The exclusion criteria were shoulder symptoms referred from cervical region, signs of acute inflammation or severe pain that resulted in difficulty to move the upper extremity, chronic adhesive capsulitis, suspected rotator cuff tears, suspected glenoid labrum tear, history of shoulder or neck surgery, fractures of shoulder-linked bones, observable scoliosis and severe kyphosis, history of the neurological conditions affecting movement, received corticosteroid injection on the shoulder within previous 30 days, and elite professional athletes and high-level weight training.

There were 45 patients (11 males, 34 females) with chronic shoulder pain eligible and agreed to participate. Although five patients had shoulder pain in both arms, the examinations randomly selected one of the shoulders for assessment. Most of the participants were right-hand dominant (91.11%) but the shoulder pain was more on the left side (64.44%). The disability level was measured using Disability of the Arm, Shoulder, and Hand (DASH) questionnaire. The characteristics of participants are presented in Table 1.

Table 1. Characteristics of the participants ($n = 45$).

Characteristics	Mean	SD	% (n)
Age (years)	39.49	10.98	
Gender distribution	—	—	
Male			24.44 (11)
Female			75.56 (34)
Body mass index in kg/m^2	24.26	3.94	—
Side of pain	—	—	
Right			35.56 (16)
Left			64.44 (29)
Duration of shoulder pain (months)	6.82	4.62	—
VAS (after testing)	3.2	2.11	—
DASH total score (%)	21.33	14.83	—
DASH work score (%)	21.17	20.27	—

Note: DASH = Disability of the Arm, Shoulder, and Hand, VAS = Visual Analog Scale.

All participants signed an informed consent before the study. The research protocol was approved by the Mahidol University Central Institutional Review Board and Siriraj Hospital (MU-CIRB 2016/074.1905). The estimation of sample size required was performed with the following criteria: a two-tailed test at the level of significance of $\alpha = 0.05$; minimal kappa of clinical significance of 0.40; expected kappa between examiners of 0.80; and expected agreement between examiners of 0.70.[16] The appropriate number of sample size for this study at 80% sufficient power was 48. However, three patients refused to participate in the study during data collection therefore total participants in this study were 45.

The MSI standardized examination procedure

The MSI standardized examination of shoulder according to Sharmann's textbook was used to classify patients with shoulder pain into specific categories of movement impairment syndromes.[8] Two main parts of the examinations included (1) a series of alignment and movement tests in several positions to identify the possible movement impairments, and (2) tests of the strength and length of related muscles to identify the contributing factors. The operational definitions, procedures for each test item and the criteria for classifying the patients with the shoulder pain were delineated in a reference manual. The examination began with the primary test in which the patients were asked to perform preferred posture and movement pattern. The examiner observed the alignments and movements and the symptoms were notified. If the complaint was aggravated or increased during the primary test, the examiner immediately performed secondary test by correcting the alignment and/or movement. The movement was then observed and the symptoms were recorded again. The positive change of complaint during the secondary test would confirm that the alignment and/or movement pattern corrected was the possible cause of pain. The strength and length of muscles considered as the contributing factors of movement impairment were also tested. The repeated pattern of the test results indicated the movement impairment diagnosis. After completion of the examination, the patient was classified into subgroup and subcategory syndromes. The MSI classification system of shoulder consisted of two main subgroup syndromes i.e., scapular and humeral syndromes. Six scapular subcategory syndromes included downward rotated, depressed, abducted, wing, internal rotated/anterior tilted, and elevated. Three humeral subcategory syndromes were anterior glide, superior glide, and medial rotated.[8] In this study, all possible syndromes and subcategory syndromes were identified in each patient and used for the reliability analysis.

Examiners and training

Two registered physical therapists with different levels of experience in musculoskeletal field were the examiners in this study. The first examiner had 15 years of clinical experiences. She had taken a three day continuing education course on the shoulder MSI-based approach. The theory and practice of the MSI classification system as well as the categorized shoulder syndromes according to Sahrmann's textbook was presented in the course. After attending the course, she had applied the approach in her clinical practice in the past three years. The second examiner had two years of clinical experience without formal education related to the MSI approach. Both examiners participated in a standardized training program which consisted of three main sessions; didactic (1 week), hands-on practice (4 weeks), and verification sessions (2 weeks). The didactic period aimed to review and clarify the related anatomy, biomechanics, the concept of MSI and the operational definition of each test item in the standardized examination. The hands-on practice session focused on using the MSI approach in both asymptomatic and symptomatic individuals and making decision of diagnosis according to the assigned criteria. Lastly, the verification session focused on diagnostic accuracy of classification verified by an expert instructor who had taken a continuing education course on the MSI-based shoulder classification as well as teaching and applying the MSI concept in her clinical practice for eight years. At the end of this session, both examiners were able to independently evaluate and classify all six symptomatic subjects for preliminary session, the agreement of their evaluations was perfect.

Assessment procedure

All participants were screened to determine the eligibility by another physical therapist. The demographic data and clinical outcomes, including pain intensity and shoulder functions were interviewed and recorded. This information was not known by two examiners who performed the MSI examination procedure.

During the MSI assessment, the participants exposed their upper thoracic and shoulder regions i.e., females wearing sports bras and males taking off their shirts. The shoes were also taken off. Participants were asked to assume a natural relaxed standing on a reference line marking the feet position. Two examiners performed the same series of testing beginning with the alignment testing in standing position and used the adhesive markers to mark the superior and inferior angles of the scapula. These markers were completely removed after each examiner finished the examination.

Both examiners assessed each participant on the same day. The order of which examiner to perform first, the testing was randomly determined by drawing number from a sealed envelope. The first examiner evaluated the participants independently in a private room. After the first examiner finished the evaluation, the participants were asked to rest about 15 min and pain level was reevaluated by the therapist who performed the screening. Then, the second examiner evaluated the same participants independently in the same private room. The patients were emphasized not to mention any information about the previous testing session to the other examiner. After finished the examination, the participants were asked to determine their pain level again. All test results and final movement diagnoses were recorded in a standardized assessment form. Both examiners did not discuss about the evaluation procedures and were blinded to the results of each other during testing session. They determined the MIS classification both subgroup and subcategory syndromes based on the most consistent pattern of alignments and movements observed throughout the examination considering the symptom patterns of patients. The positive findings of syndromes and subcategory syndrome were the alignment and movement directions of the scapula and humerus that provoked symptom and reduced with the correction. The syndrome(s) of scapular and/or humeral were identified. Then, the specific subcategory of each syndrome was also specified according to the criteria (Appendix A). The MSI classification was not mutually exclusive, therefore more than one syndrome and subcategory syndrome could be identified in each patient.

Data analysis

The statistical analysis was performed by using SPSS software (SPSS Inc. Release 2009. PASW Statistics for windows, Version 18.0, Chicago: SPSS Inc.). The descriptive statistics was used for determining the demographic data, shoulder functional activity and percentage of the frequency of the movement impairment in subgroups and their subcategories. The intertester reliability of the MSI classification system including subgroup and subcategory syndromes was calculated. The percent agreements of each subgroup and subcategory syndromes were reported and the kappa statistics was used as the chance-corrected agreement between examiners. The kappa values were interpreted as follows: less than 0.20 indicated slight agreements, 0.21–0.40 fair agreement, 0.41–0.60 moderate agreement, 0.61–0.80 substantial agreement, and more than 0.80 almost perfect agreement.[17] The kappa value above 0.40 was generally considered acceptable.[12] A p-value of < 0.05 was considered statistically significant.

Results

Both examiners identified all participants with shoulder pain as having impairments of both subgroup and subcategory syndromes of the MSI classification system. The percentage of agreement between both examiners of identifying the MSI syndromes was 100% in all participants. However, the number of participants without MSI was zero, therefore the kappa value was not computable.

To identify if the patients had scapular, humeral or both syndromes, the percent agreements was 71.11%, with fair level of chance correction agreement ($K = 0.34$, $p = 0.003$, 95% CI 0.00, 0.64). The frequencies and percentages of the MSI syndrome(s) identified by two examiners are presented in Table 2.

In particulars, two examiners did not agree that patients had which syndrome in 13 of 45 shoulders. Examiner 1 identified scapular syndrome in all patients, 76% had scapular syndrome only and 24% had both syndromes. Examiner 2 identified scapular syndrome in 96% of patients, 64% scapular syndrome only, 31% had both syndromes, while 4% were determined as having humeral syndrome only.

For subcategory syndromes based on the MSI classification system, the frequencies and percentages of each MSI subcategory syndromes identified by two examiners are presented in Table 3.

Since the subcategory identifications were not mutually exclusive, a patient could therefore be identified as having more than one subcategory syndrome. Overall, the scapular winging was the most frequently identified by both examiners, followed by scapular depression and scapular downward rotation. For humeral syndrome, superior gliding syndrome was the most frequently observed in patients with shoulder pain.

The intertester reliability between two examiners of each subcategory syndrome are also presented in Table 3. The percentages of agreement of the MSI subcategory syndromes ranged from 73% to 91%. The scapular depression and humeral superior gliding syndromes had substantial levels of agreement ($K = 0.64$ and 0.66) in patients with shoulder pain. The scapular downward rotation and winging had moderate agreement ($K = 0.57$ and 0.46). The scapular abduction and humeral anterior glide syndrome had fair agreement ($K = 0.32$ and 0.30) and scapular internal rotation/tilt had poor agreement ($K = 0.20$). None of

Table 2. Frequency and percentage of the MSI syndromes in patients with shoulder pain ($n = 45$).

		Classification by Examiners 2			
	Subgroup syndromes	Scapular syndrome only	Humeral syndrome only	Both syndromes	Total
Classification by Examiner 1	Scapular syndrome only	26 (57.78%)	0 (0%)	8 (17.78%)	34 (75.55%)
	Humeral syndrome only	0	0	0	0
	Both syndromes	3 (6.67%)	2 (4.40%)	6 (13.30%)	11 (24.44%)
	Total	29 (64.44%)	2 (4.44%)	14 (31.11%)	45 (100%)

Table 3. Frequency, percentage and the intertester reliability of the subcategory syndromes in patients with shoulder pain ($n = 45$ shoulders).

	Examiners 1		Examiners 2		Intertester reliability	
Subcategory syndromes	n	%	n	%	% agreement	Kappa
Scapular downward rotation	15	33.33	18	40.00	80.00	0.57
Scapular depression	17	60.00	23	51.11	80.00	0.64
Scapular abduction	13	28.89	11	24.44	73.33	0.32
Scapular winging	33	73.33	31	68.89	77.78	0.46
Scapular internal rotation/tilt	2	4.44	6	13.33	86.67	0.20
Scapular elevation	0	0	0	0	—	.[a]
Humerus anterior glide	5	11.11	10	22.22	80.00	0.30
Humerus superior glide	6	13.33	8	17.78	91.11	0.66
Humerus medial rotation	0	0	0	0	—	.[a]

Note: .[a] represents the measure of association was not computed because at least one response for the item was a constant.

the examiners identified the movement impairment of scapular elevation and humeral medial rotation syndromes in any patient with shoulder pain, therefore the kappa value was not computed.

From the results, the individual subcategory syndromes might have acceptable reliability or agreement between the two examiners, but the overall agreement and kappa value of the MSI classification of subcategory syndromes was slight ($K = 0.112$; 95% CI 0.048–0.176). Table 4 shows the 2×2 table for each subcategory syndrome including the frequency and the percentage of agreement.

Discussion

This study examined the intertester reliability of the MSI classification in patients with shoulder pain. The percent agreement to identify syndromes between two physical therapists who had different levels of experience was 71.11% with fair level of agreement ($K = 0.34$). The percent agreement range of scapular subcategories syndrome identification was 73–87% and humeral subcategories syndrome was 80–91%. The identification of subcategories syndrome also had agreements levels ranged from poor to substantial i.e., kappa from 0.20 to 0.66. Substantial level of agreements was observed in the diagnosis of scapular depression and the humeral superior gliding syndromes.

The varied levels of agreement in this study was possibly due to two main factors i.e., symptom fluctuation between two examination sessions, and the different evaluation skills of two examiners. First, this study assessed the intertester reliability by having two assessors independently examined the patients. The advantage of blinding the assessors from each other is that it would better reflect the nature of clinical practice. However, two separate examination sessions might bring about different responses of patients especially in symptom aggravation and relieving during the primary and secondary tests which was the key issue for determining subcategory syndromes. For this, we monitored the pain intensity before and after each examining session. The differences of pain levels at the beginning of two sessions were not more than 10 mm. However, some previous studies have raised concerns that repeated examination of a patient is likely to change the patient's presentation and adversely impact the assessment of reliability.[12,18,19]

Compared with a previous study[15] that investigated the intertester reliability of the MSI classification among three novice physical therapists in patients with knee pain, our study had slightly lower level of agreements. In the knee pain study, only one examiner performed the MSI evaluation and the other two examiners observed and assigned the diagnosis to avoid the effect of repeated testing on each patient. However, the cues from examination responses might lead to better agreements among examiners. Moreover, another MSI reliability study in patients with low back pain[11] found almost perfect agreement when having the examiners classified the patients into movement impairment subgroups syndrome using the same recorded data.[10] In fact, the paper case method

Table 4. The frequency and the percentage of agreement of each subcategory syndromes in patients with shoulder pain.

Subcategory syndromes		Classification by Examiners 2									
		DW	DP	AB	W	IR/T	E	AG	SG	MR	Total
Classification by Examiner 1	DW	12 (26.67%)	9 (20.00%)	3 (6.67%)	11 (24.44%)	3 (6.67%)	0 (0%)	5 (11.11%)	2 (4.44%)	0 (0%)	45 (16.79%)
	DP	10 (13.89%)	21 (29.17%)	7 (9.72%)	16 (22.22%)	6 (8.33%)	0 (0%)	7 (9.72%)	5 (6.94%)	0 (0%)	72 (26.87%)
	AB	3 (9.68%)	7 (22.58%)	6 (19.35%)	7 (22.58%)	1 (3.23%)	0 (0%)	3 (9.68%)	4 (12.90%)	0 (0%)	31 (11.57%)
	W	14 (17.28%)	14 (17.28%)	6 (7.41%)	27 (33.33%)	7 (8.64%)	0 (0%)	8 (9.88%)	5 (6.17%)	0 (0%)	81 (30.22%)
	IR/T	0 (0%)	1 (20.00%)	1 (20.00%)	2 (40.00%)	1 (20.00%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	5 (1.87%)
	E	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
	AG	4 (22.22%)	2 (11.11%)	1 (5.56%)	5 (27.78%)	3 (16.67%)	0 (0%)	3 (16.67%)	0 (0%)	0 (0%)	18 (6.72%)
	SG	1 (6.25%)	2 (12.50%)	2 (12.50%)	4 (25.00%)	0 (0%)	0 (0%)	2 (12.50%)	5 (31.25%)	0 (0%)	16 (5.97%)
	MR	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
	Total	44 (16.42%)	56 (20.90%)	26 (9.70%)	72 (26.87%)	21 (7.84%)	0 (0%)	28 (10.45%)	21 (7.84%)	0 (0%)	268 (100%)

Note: DW = downward rotation, DP = depression, AB = abduction, W = wing, IR/T = internal rotation/anterior tilt, E = elevation, AG = anterior glide, SG = superior glide, MR = medial rotation.

also removed other confounding factors such as examination performance which highly influenced on the reliability.

Second, the different clinical experiences, both general clinical practice and the MSI concept, of two examiners in this study might be important factors affecting level of agreements. The differences of experience in musculoskeletal management might influence the agreements of examination because the MSI evaluation composed of the observation and manual skills commonly used in the physical therapy clinic. Similar to our study, Harris-Hayes and Van Dillen[10] assessed the intertester reliability of the MSI classification of low back pain which two examiners using separate examination sessions with standardized physical examination form. Compared to our results, their results were more reliable (83% agreement, K – 0.75–0.99). However, both examiners in their study had over 10 years of clinical experience and one examiner was a certified clinical specialist in orthopedic field and used the MSI concepts in her clinical practice for seven years while another examiner was new for the MSI approach.

The intensive training session and the reference manual were used to standardize the examination and decision procedure since these processes were suggested to be effective to improve the level of agreements of the movement diagnosis.[10,15] Harris-Hayes and Van Dillen[10] suggested that the specific guideline for each test item in details and explicit rules of classification, as well as rigorous training were the key for improving the level of reliability. In addition, the strict practice and training of examiners might reinforce the confidence of clinical judgments.[10] With the intensive training session, the percent agreements in our study were generally acceptable for both subgroup and subcategory syndromes identifications. Although both examiners did not learn from the developer of the concept, they could apply the MSI approach to evaluate and identify the MSI subgroup and subcategory syndromes with somewhat acceptable agreement in the patients with shoulder pain. This would make greater generalizability of the use of this concept among physical therapists.

Another concern of the results was the use of kappa statistics which has the chance correction reliability coefficient. The low kappa coefficient in some categories seemed to relate to the skewed response distribution i.e., the small number of some response categories due to the characteristics of the study sample.[20] For examples, the numbers of responses in "humeral syndrome only" and the subcategories of "scapular internal rotation/tilt" were very low and these were corresponded with the low kappa coefficients of these two categories. There were also two subcategories i.e., scapular elevation and humeral medial rotation which were not identified in any participants in this study and the kappa value could not be calculated. More studies which used greater variety of patients with symptoms and examination responses are then required to confirm the agreement of therapists.

Additionally, the great number of subcategory syndromes might contribute to the poor overall agreement of the MSI classification of shoulder subcategory syndromes. Shoulder classification has nine subcategory syndromes compared with five subcategory syndromes for low back pain[10–12] and six subcategory syndromes for knee disorders.[13–15] With greater number of subcategory syndromes and inadequate number of subjects presented in each subcategory syndrome, the computed kappa value would be low. Moreover, the reliability is the prerequisite for validity of a classification system. The low reliability of the MSI classification for shoulder disorders will then threaten its validity.

Another concern which might distress the validity of a shoulder MSI classification system examined in this study is the non-mutually exclusive of its subcategories. The subcategories of this classification might need to be reviewed to meet the fundamental requirement for a valid classification system i.e., mutually exclusive and exhaustive category.[21]

The clinical assessment of humeral and scapular position and motion are apparently challenging due to the large muscles mass and complex movement patterns.[22] The reported kappa coefficients for identifying scapular abnormal positions and movements in previous studies were commonly poor to moderate.[23–26] The results of kinematic studies of humeral movement impairments were also inconsistent.[27,28]

The results suggested that the movement and alignment alteration of both scapula and humerus were coexisting with shoulder pain. The scapular syndromes were identified in 96–100% of participants in this study. The patterns most observed were winging (70–72%), depression (48–56%), and downward rotation (34–38%). A previous study[29] suggested that the scapular kinematic changes were observed in 68–100% of individuals with shoulder injury. For shoulder dysfunction, the altered scapular movements were reported to be decreased posterior tilting and upward rotation, and increased scapular elevation.[30] Specifically, the most frequent findings for SIS were reduced scapular posterior tilting, reduced upward rotation, increased internal rotation, as well as increased clavicular elevation.[31] Additionally, increased humeral head superior or anterior translation had been found in subjects with impingement.[32,33] However, different alterations of scapular movement were reported in different shoulder pathologies.[31]

There were some limitations in this study. First, the symptom status of patients over two examination sessions might change, although we monitored subjective symptom by rating the pain intensity at the beginning and end of each session and made certain that the symptom levels were equal. Previous investigators have suggested that poor reliability for items related to the symptoms elicited may have resulted from using a repeated testing (test–retest) design.[10,11,15] The effect of the repeated assessment and corrected alignment and movement might also cause learning and changing of the pattern of movement and symptom response. Another limitation was that most subjects in this study had mild to moderate levels of shoulder pain and disability. The results might be different if subjects with greater pain and disability levels were included. There were also less number of subjects with some movement impairment patterns including humeral syndrome only and scapular internal rotation/tilt. None of subjects was identified as having scapular elevation and humeral medial rotation. The examiners in this study had different clinical experiences and education regarding the MSI approach. Both of them also did not receive the training from the approach developer. More research is needed to concentrate on examiners with wider ranges of characteristics in terms of clinical experiences and familiarity to the classification system.

Conclusion

This study showed generally acceptable to poor reliability of two physical therapists with different levels of experience to classify the MSI. However, the novice therapist with intensive training was able to diagnose patients with shoulder pain with fair agreements referenced with the more experienced therapist. The great number of categories of the shoulder MSI classification system might be a factor for the poor agreement level which considering the possibility of the agreement occurring by chance. The insufficient agreements in this study were also possibly associated to symptom changes between two separate examination sessions, and the absence of patients classified in some subcategories.

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Conflict of Interest

The authors have no conflict of interest relevant to this paper.

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Author Contributions

All authors conducted the conception and design of the study. VM and TP performed the assessment procedure, an acquisition, analysis, interpretation of the data, and drafting of this paper. All authors revised and approved the final paper.

Appendix A. Classification of Movement System Impairment of Shoulder Girdle

Table A.1.

Subcategory syndromes	Alignment impairments	Movement impairments
1. Scapular syndrome		
1.1. Scapular downward rotation	– The vertebral border of scapula is not parallel to midline and the inferior angle is closer to midline compared with the superior border or root of scapular spine. – The scapula may be adducted in resting position. – Forward shoulder. – Increased slope of shoulder level. – Abduction of the humerus can be secondary to the downward rotated position of the scapula.	– Insufficiency of scapular upward rotation or glenohumeral elevation or both during the final phase of shoulder elevation. – The scapular downward rotation during the first 60° of shoulder flexion and 30° of shoulder abduction. – The inferior angle of the scapula not reach to the midaxillary line of the thorax during shoulder full elevation.
1.2. Scapular depression	– The superior angle of scapula is lower than the second of thoracic vertebral spinous process. – The clavicles is placed on horizontal or slightly lower lateral than medial. – Slope of shoulder is increased. – Involved arm is longer than uninvolved arm.	– Insufficiency of scapular elevation during shoulder flexion and abduction. – The acromion process depressed in the first 90° of arm elevation or not elevated after 30° of arm elevation.
1.3. Scapular abduction	– The distance between the vertebral of spinous process and vertebral border of scapula is greater than three inches and resting scapular greater than 30° and anterior to frontal plane. – The position of glenohumeral joint is placed on anterior than normal alignment.	– Excessive scapular abduction during shoulder flexion and abduction. – Axillary border of scapula protrudes to lateral greater than 1/2 inches beyond the thorax at the end of shoulder flexion and abduction. – In prone position, scapular abduct during shoulder lateral rotation. – Scapulohumeral rhythm altered to 1:1 ratio during the phase of shoulder flexion from about 90–180°.

Table A.1. (*Continued*)

Subcategory syndromes	Alignment impairments	Movement impairments
1.4. Scapular winging	– The medial border of scapular is prominent from rib cage and scapular internal rotation is more than 40°.	– The vertebral border of scapular winged during shoulder flexion and abduction as well as during return to shoulder flexion.
1.5. Scapular internal rotation and anterior tilt	– For scapular internal rotation, the scapula is rotated more than 30–40° anterior to frontal plane. – For scapular tilting, the scapular is tipped forward from rib cage and prominence of inferior angle of scapula and the scapular anterior tilt more than 15°.	– Insufficiency of scapular external rotation and posterior tilt at the end range of arm elevation.
1.6. Scapular elevation	– The alignment of scapula is above 2nd and 7th thoracic vertebral spinous process. – Decreased slope of shoulder girdle and increased upward slope of clavicle.	– Excessive of scapular elevation at any period of shoulder elevation.
2. Humeral syndrome		
2.1. Humeral anterior glide	– Greater than one third of humeral head is positioned anterior to acromion process. – Shoulder is in forward position. – The humeral head is anterior to the distal end of humerus. – The indentation is observed below the acromion in the posterior aspect.	– Excessive or abnormal of humeral anterior gliding during shoulder abduction, horizontal abduction, return to flexion, medial or lateral rotation, and elbow extension. – Humeral anterior gliding might occur during prone position and active shoulder lateral rotation than passive. – Humeral anterior gliding and pain might occur during shoulder rotation in the frontal plane than scapular plane. – Horizontal adduction might produce pain at anterior shoulder due to insufficiency of humeral posterior gliding. – Accessory joint motion increased anteriorly and decreased posteriorly.
2.2. Humeral superior glide	– Decreased subacromial space. – The humerus is in abduction position relative to scapula. – The scapula is positioned as depression or downward rotation.	– Insufficient inferior gliding of humerus head during shoulder elevation. – Excessive humeral superior glide during shoulder flexion, abduction, and medial or lateral rotation. – Decreased distance between humeral head and base of neck at the end range of arm elevation.
2.3. Humeral medial rotation	– Medial rotation of humerus in resting position. – Forward shoulder.	– Insufficiency of lateral rotation of humerus during shoulder elevation. – Excessive humeral medial rotation during shoulder flexion and abduction.

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Pilot study on comparisons between the effectiveness of mobile video-guided and paper-based home exercise programs on improving exercise adherence, self-efficacy for exercise and functional outcomes of patients with stroke with 3-month follow-up: A single-blind randomized controlled trial

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Objective: To compare the effectiveness of mobile video-guided home exercise program and standard paper-based home exercise program.
Methods: Eligible participants were randomly assigned to either experimental group with mobile video-guided home exercise program or control group with home exercise program in a standard pamphlet for three months. The primary outcome was exercise adherence. The secondary outcomes were self-efficacy for exercise by Self-Efficacy for Exercise (SEE) Scale; and functional outcomes including mobility level by Modified Functional Ambulatory Category (MFAC) and basic activities of daily living (ADL) by Modified Barthel Index (MBI). All outcomes were captured by phone interviews at 1 day, 1 month and 3 months after the participants were discharged from the hospitals.
Results: A total of 56 participants were allocated to the experimental group ($n = 27$) and control group ($n = 29$). There were a significant between-group differences in 3-months exercise adherence (experimental group: 75.6%; control group: 55.2%); significant between-group differences in 1-month SEE (experimental group: 58.4; control group: 43.3) and 3-month SEE (experimental group: 62.2; control group: 45.6). For functional outcomes, there were significant between-group differences in 3-month MFAC gain (experimental group: 1.7; control group: 1.0). There were no between-group differences in MBI gain.
Conclusion: The use of mobile video-guided home exercise program was superior to standard paper-based home exercise program in exercise adherence, SEE and mobility gain but not basic ADL gain for patients recovering from stroke.

Keywords: Physiotherapy; stroke; rehabilitation; exercise; adherence; self-efficacy; functional outcome; video; home.

Introduction

Stroke, also known as cerebrovascular accident, is an acute disturbance of focal or global cerebral function with signs and symptoms lasting more than 24 h or leading to death presumably of vascular origin.[1] It is the third leading cause of death in Hong Kong after cancer and heart disease. More than 3000 people died in Hong Kong each year for this condition.[2] The most widely recognized impairment caused by stroke is motor impairment, which restricts function in muscle movement or mobility.[3,4] It was shown that patients with stroke who had as much practice as possible within 6 months after stroke onset could achieve the best functional outcome.[5–7]

In Hong Kong, under the service model of Hospital Authority, patients would be referred to ambulatory services, such as geriatric day hospital, or domestic physiotherapy services to continue their stroke rehabilitation after discharge from hospital. However, some patients could not attend ambulatory services due to various difficulties, such as transportation and absence of carers. The low frequency of domestic physiotherapy service also reduced the effectiveness of rehabilitation of patients. From our local data, around a quarter of home-care patients have not received any further rehabilitation training from ambulatory or domestic physiotherapy services. Among this population, there were approximately 56% of them rated to be Modified Functional Ambulatory Category (MFAC) 2–5, who may have had higher potential of improvement in stroke outcomes if appropriate rehabilitation training was given.[8] Home-based exercise program would be a good choice for filling this post-discharge gap of rehabilitation continuation.

Traditionally, for continuation of exercise training program, physiotherapists would prescribe home exercises programs in paper-based format.[9,10] However, evidence showed that home exercise prescription in paper-based format does not lead to better adherence to a home exercise program compared to having no written and pictorial instructions for patients with stroke less than four months.[10]

The recent increasing accessibility of smart technology[11] offers an opportunity to advance the mode of delivery of home exercise program by mobile devices such as video-guided exercise on electronic tablets[12] and video-guided exercise on mobile apps.[13] However, the effects of mobile video-guided exercise programs were controversial. A study showed that home exercise programs filmed on an electronic tablet, with an automated reminder, were not superior to standard paper-based home exercise programs in terms of adherence, motor function, or satisfaction for patients recovering from stroke.[12] In contrast, another study showed that people with musculoskeletal conditions who adhere better to their home exercise programs in video-based format are provided with an app with remote support compared to paper handouts; although the clinical importance of this added adherence is unclear.[13]

Since one of the major outcomes to evaluate the effectiveness of the mode of delivery of home exercise program is adherence,[10,12,13] it is worthwhile to study the factor affecting adherence of mode of delivery of home exercise program. It was suggested that one of the barriers to adherence of home exercise is low self-efficacy.[14,15] According to the theory of self-efficacy, self-efficacy is defined as a person's confidence in their ability to perform a task.[16] Thus, self-efficacy plays an important role in maintaining the exercises behavior after stroke[17–19] and improving self-efficacy for exercise (SEE) could influence long-term exercise behavior as well as the early stages of exercise adoption.[20–23] Another factor affecting adherence of home exercise was the delivery mode of training program.[13] Studies showed that visual information brings more benefits to patients than verbal information alone.[24–27] Adherence of home exercise program has positive correlation with physical function and physical performance of patients.[15,28]

It is worthwhile for physiotherapists to investigate the mode of delivery to enhance exercise adherence and self-efficacy of post-discharge home exercise for patients with stroke. The objective of the study is to compare the effectiveness of video-guided exercise program and standard paper-based home exercise program on adherence of exercise, self-efficacy and functional outcomes in patients with stroke within 3-month follow-up.

Methods

A randomized, controlled, assessor-blinded clinical trial was conducted between July 2018 and June 2019. Participants were recruited from the inpatient Stroke Rehabilitation Program in the Department of Medicine and Geriatrics of Tai Po Hospital and Shatin Hospital. The two hospitals provided multidisciplinary inpatient stroke rehabilitation to more than 1000 stroke patients yearly. All those stroke patients were diagnosed with acute stroke and were transferred from all the three acute hospitals in New Territories East Cluster. The hypothesis was that participants prescribed with video-guided home exercise will demonstrate higher adherence of exercise, better self-efficacy and better functional outcomes when compared with the participants in paper-based exercise prescription group.

Participants were eligible for inclusion if their principle diagnosis was stroke, participants or their carers have smart devices such as smart phones or tablets that are able to scan QR code and connect to the Internet as well. All the participants or carers could read Chinese. They were excluded if (i) could not follow gesture and instructions; (ii) MFAC upon discharge was below 2 or above 5, (iii) no smart device for video and (iv) refusal.

This was a single-blinded randomized study. The study procedure flowchart is presented in Appendix B. Before enrolment and randomization, potential participants were screened by their case therapists to ensure they met the inclusion criteria and none of the exclusion criteria. Eligible participants were then randomly assigned to either Intervention Group or Control Group in a 1:1 ratio. Investigators who were responsible for data collection were blinded to the group allocation. A randomization list was developed by personnel who were not involved in this study and who would not have any contact with the study participants. The details of the list were unknown to any of the investigators and study coordinators, and were contained in a set of sealed, sequentially numbered envelopes. Each enrolled participant was allocated to the next sequential number on the list. All research study personnel, including those who collect data and assess outcomes, were blinded to the group assignment. The envelopes and the randomization list were not revealed to any of the study personnel until completion of recruitment and data collection.

Research team adopted per-protocol analysis method and provided two brief sessions to all physiotherapists of the stroke units to inform the process of subject recruitment of potential participants. Case physiotherapists would inform research team for subject recruitment once potential participants have discharge plan, usually 1–2 weeks before discharged. Case physiotherapists provided brief information about the study to potential participants or their carers before their discharge from hospitals. Research team approached the participants and gave detailed information about the study and verifies their interest in participating once verbal consent was obtained. The Joint Chinese University of Hong Kong — New Territories East Cluster Clinical Research Ethics Committee (The Joint CUHK-NTEC CREC) approval was obtained prior to the commencement of the study. This trial design was registered prospectively with the ClinicalTrials.gov Protocol Registration and Results System (ClinicalTrials.gov ID: NCT03509363). Written informed consent was obtained from all participants.

Pre-discharge training sessions lasting for 10–15 min were provided to participants, and their carers if any, of both groups in order to make them familiar with the selected home exercises and the technique of using mobile phone to scan QR for intervention group. Participants allocated to the intervention group were prescribed a set of exercise video with QR code provided in home exercise pamphlets and they had to perform the prescribed exercises under the guidance of the videos. On the other hand, participants in control group were given instructions for their home exercise program in a traditional pamphlet includes photographs and instructions of exercise demonstration. The content of home exercise program in both groups was the same and was based on the recommendations from the National Stroke Foundation Clinical Guidelines, included nine arm control exercises, six leg control exercises, six truck control exercises and four mobility exercises (Table 1).

Table 1. Type of home exercises in both experimental group and control group.

Arm control exercise
1. Shoulder elevation in lying (Active)
2. Shoulder elevation in lying (Active-assisted)
3. Elbow flexion/extension (Active)
4. Elbow flexion/extension (Active-assisted)
5. Shoulder elevation in sitting (Active)
6. Shoulder elevation in sitting (Active Assisted)
7. Weight-bearing to affected arm (Active)
8. Shoulder horizontal abduction/adduction (Active)
9. Hand grasp and release (Active)
Leg control exercise
1. Hip abduction/adduction in lying (Both leg) (Active)
2. Hip abduction/adduction in lying (Affected leg) (Active)
3. Hip abduction/adduction in lying (Both leg) (Active-assisted)
4. Hip and knee flexion/extension in lying (Active)
5. Hip and knee flexion/extension in lying (Active-assisted)
6. Knee extension in sitting (Active)
Trunk control exercise
1. Trunk rotation (Active)
2. Trunk rotation (Active-assisted)
3. Double-leg bridging (Active)
4. Single-leg bridging (Active)
5. Double-leg bridging (Active-assisted)
6. Forward reaching (Active)
Mobility
1. Sit to stand (Active Assisted)
2. Weight-shifting in sideway (Active Assisted)
3. Stepping back and forward (Active Assisted)
4. Semi-squat (Active Assisted)

The doses for the participants were prescribed by their case physiotherapists according to the needs and abilities of participants. The total number of home exercise varied from 3 to 5 and the treatment frequencies of each exercise varied from daily to 3 times per day so the course length varied from 10 to 30 min daily. Participants' needs and the abilities were defined as amount of assistance and the mobility by participants' pre-discharge MFAC.

All participants were screened by their case physiotherapists according to exercise prescription guidelines of American College of Sports Medicine[29] for any contraindication for exercise. Only patients who were medically fit for exercise were recruited. Exercise-related adverse events such as chest tightness or pain, dizziness, and/or trip, stumbles, or falls might happen during exercise but which was not as higher risk than the usual prescription of home exercises. Suitability of participating home exercise program will be assessed by physiotherapists based on environmental risk, fall risk, and competence of participants or carers in performing exercise with participants.

All participants' data related to the research were collected in data collection sheets by case therapists of the patients. The data in the data collection sheets were transferred to a database in Excel format that could be accessed only by the research team members. Therefore, we could judge which participants were included in the analysis. Data on patients' demographics, gender, age, site of lesion, side of stroke, type of stroke, education level, experience of using mobile device, present of complication such as neglect and dysphasia, cardiovascular risk factors and availability of carer, were retrieved from Central Management System of Hospital Authority by case therapists of the patients.

Outcome measures including self-reported exercise adherence, self-efficacy for exercise (SEE-C), MFAC, and Chinese version of the Modified Barthel Index (MBI) were assessed on phone follow-up basis by a blinded-assessor at 1 day, 1 month, and 3 months after the participants were discharged from hospitals. For between group comparisons, since participants had difference baseline functional status, baseline functional status affects MBI and MFAC but not SEE and Adherence, therefore MBI gain and MFAC gain were used to compare the improvement of functional status for fair comparisons. In addition, since we directly compared Adherence and SEE that 3 time points were tested; while we compared MBI gain and MFAC gain that only 2 time points were tested i.e., 1-month gain (1-month minus baseline) and 3-month gain (3-month minus baseline).

Self-reported exercise adherence

Since there has no well-developed measures that capture self-reported adherence to prescribed but unsupervised home-based rehabilitation exercises; and since we interviewed the participants by phone, some details could not be recalled. So we adopt the concept visual analogue scale to ask the adherence by percentage (0–100%) as a total effect of adherence of number of session, daily frequent, repetition, set and quality of movement of the whole review period. The exercise adherence was measured by asking participants to report their percentage of exercise completion between 3 period of time i.e., from discharge to 1 day post-discharge, from 1 day post-discharge and 1-month post-discharge and from 1-month post-discharge to 3-month post-discharge during phone follow-up. Log sheets were not used since it was reported that log sheet that needs to be filled out regarding the completion of each exercise would serve as a reminder and a motivational track record for the patient and assists patients in improving their adherence.[31]

Chinese version of self-efficacy for exercise (SEE-C)

An original English version of the SEE scale was designed to test people's confidence to continue exercising in the face of barriers to exercise.[32] This scale has a range of total scores from 0 to 90. A higher score indicates higher SEE. Estimates of the reliability and validity of the nine item SEE scale have been widely tested and shown to be valid for use in various settings, with internal consistency ($\alpha = 0.93$) and validity with efficacy expectations significantly related to exercise activity, and factor loadings all greater than 0.50.[33–35] The Cronbach's alpha coefficient of Chinese version of the SEE scale was 0.75[35] and Pearson's correlation revealed a statistically significant correlation between perceived health and SEE-C score ($r = -0.17$, $p = 0.019$).[35]

Modified functional ambulatory category (MFAC)

The MFAC was a 7-point Likert Scale (1–7) that was used to classify a patient's walking capacity. Gait was divided into seven categories, ranging from no ability to walk and requires manual assistance to sit or is unable to sit for 1 minute without back or hand support (MFAC 1) to the ability to walk independently on level and non-level surfaces, stairs, and inclines (MFAC 7).[36] The inter-rater reliability of the MFAC (intraclass coefficient [ICC]) was 0.982 (0.971–0.989), with a kappa coefficient of 0.923 and a consistency ratio of 94% for stroke patient[37] and the ICC of the MFAC in patients with hip fractures is 0.96, with a construct validity of $r = 0.81$ on the Elderly Mobility Scale (EMS).[36] Participants will be asked to describe their current mobility status via phone follow-up.

Chinese version of the modified barthel index (MBI-C)

MBI was used to assess patients' basic activities of daily living (ADL) in this study. MBI measures the participant's performance on 10 functional items including self-care, continence, and locomotion. The values assigned to each item was based on the amount of physical assistance required to perform the task and added to give a total score ranging from 0 to 100 (0 = fully dependent, 100 = fully independent) with higher score indicating higher levels of physical function.[38] There was no subtotal score because there was no subscale.[38] The internal consistency reliability coefficient for MBI was 0.90.[38] The Chinese version of MBI has been found to have good validity and reliability for assessing stroke patients.[39] A study showed that the correlations between the performance-based ADL and the interview-based ADL were r greater than 0.97 for the total score and r greater than 0.85 for most of the individual items.[40]

Although the randomization design of the study reduced the biases which could compromise the outcomes, we analyzed the confounding variables such as age, gender, type of stroke, side of hemiplegia, present of complication such as neglect and dysphasia,[41] follow-up physiotherapy such as ambulatory day hospital and domiciliary physiotherapy[42] availability of carer,[43] and experience of smart device[44] to indicate any significant association in the study.

Pair t-test and Chi-Square test were used to analysis the between-groups differences of baseline characteristics. Chi-Square test was used to analysis the between-groups of exercise adherence at all three time points i.e., baseline, 1-month, and 3-months. Independent t-test was used to analysis the between-groups of SEE, MFAC gain, and MBI gain at all three time points i.e., baseline, 1-month, and 3-months. Pair t-test was used to analysis the within-group differences between baseline to 1-month and baseline to 3-months of MFAC and MBI. The significance level was set at 0.05 for between-group analysis. All of these analyses were performed with SPSS version 18.0. Those participants with missing data due to loss of contact in phone interviews in three consecutive working days were omitted.

Results

There was a total of 115 stroke patients who were screened by physiotherapists for this study from

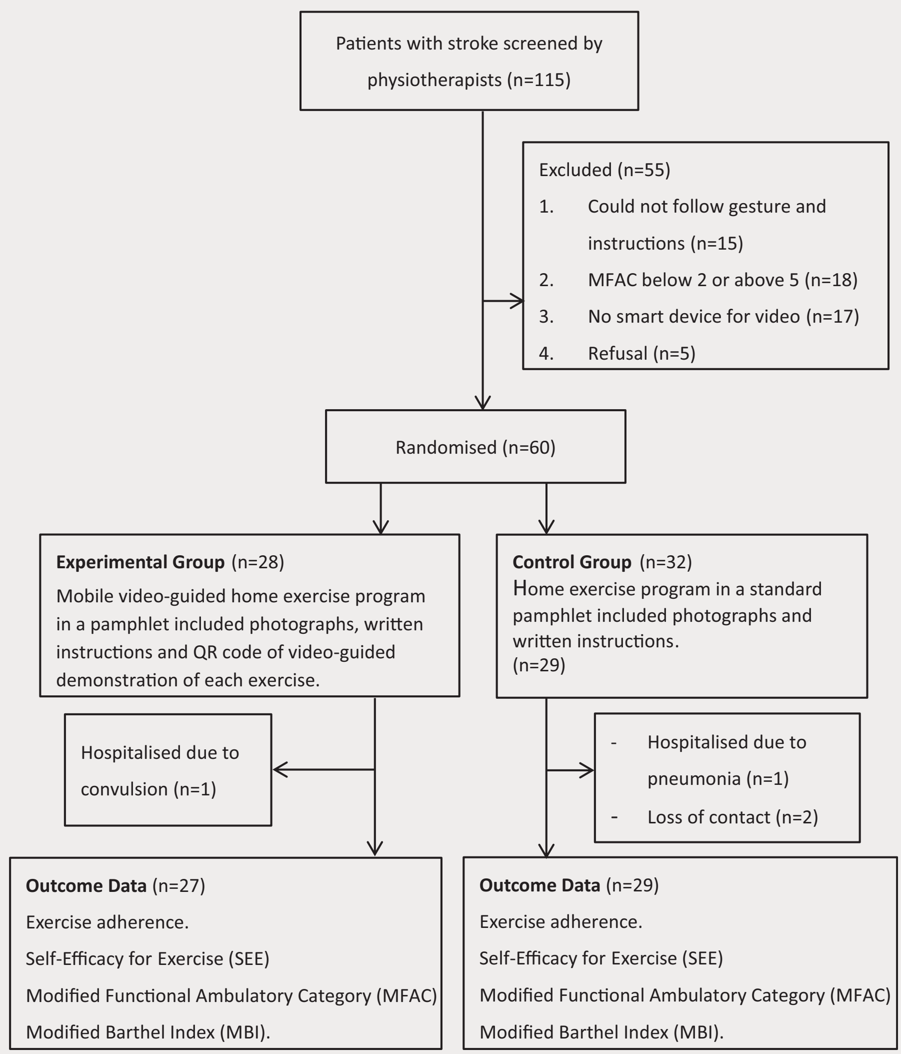

Fig. 1. Design and flow of participants through the trial.

August 2018 to March 2019. Of these, 55 participants were excluded, in which, 15 could not follow gesture and instruction; 18 had mobility below MFAC 5 or above MFAC 5; 17 had no smart device for video watching and 5 refused. The remaining 60 participants were recruited; with 28 randomly allocated to the experience group and 32 randomly allocated to the control group (Fig. 1). There were no adverse events recorded as a result of participation in this trial. Of the 60 participants, there were four withdrawals. One hospitalized due to convulsion, one hospitalized due to pneumonia and two were lost of contact. A total of 56 participants completed the study without missing data.

The groups appeared well matched and no between-group difference in age, gender, time since stroke, type of stroke, side of hemiplegia, complication, site of lesion, follow-up physiotherapy, type of carer, experience in smart device, baseline SEE and baseline MFAC but slight difference in baseline MBI. Mean age of participants was 69.8 years (SD 14.9). The mean time since stroke was 39.5 (SD 15.3) (Table 2).

There were no between-group difference in baseline adherence ($p = 0.214$), 1 month adherence

Table 2. Baseline characteristics of participants.

Characteristic	Total ($n = 56$)	Exp ($n = 27$)	Con ($n = 29$)	T-tests p	Chi-Square p
Participants					
Age (years), mean (SD), (Range)	69.8(14.9), 38–93	66.9(14.0), 40–93	72.5(15.5), 38–93	0.166	
Gender, n males (%)	31(55.4)	14(51.9)	17(58.6)		0.611
Time since stroke (days), mean (SD), (Range)	39.5(15.3), 11–89	41.3(16.5), 23–89	37.9(14.2), 11–64	0.407	
Type of stroke (%)					0.838
Infract	45(80.4)	22(81.5)	23(79.3)		
Hemorrhage	11(19.6)	5(18.5)	6(20.7)		
Side of hemiplegia (%)					0.571
Left	25(44.6)	11(40.7)	14(48.3)		
Right	31(55.4)	16(59.3)	15(51.7)		
Complication (%)					0.568
Neglect	5(8.9)	3(11.1)	2(6.9)		
Dysphasia	9(16.1)	3(11.1)	6(20.7)		
Nil	42(75.0)	21(77.8)	21(72.4)		
Site of lesion (%)					0.635
Cortex	11(19.6)	6(22.2)	5(17.2)		
Corona radiata	7(12.5)	4(14.8)	3(10.3)		
Internal capsule	8(14.3)	5(18.5)	3(10.3)		
Putamen	1(1.8)	1(3.7)	0		
Thalamus	6(10.7)	2(7.4)	4(13.8)		
Other	23(41.1)	9(33.3)	14(48.3)		
Follow-up physiotherapy (%)					0.151
Ambulatory day hospital	38(67.9)	21(77.8)	17(58.6)		
Domiciliary physiotherapy	3(5.4)	2(7.4)	1(3.5)		
Other	2(3.6)	0	2(6.9)		
Nil	13(23.2)	4(14.8)	9(31.0)		
Type of carer (%)					0.572
No	15(26.8)	10(37.0)	5(17.2)		
Spouse	11(19.6)	5(18.5)	6(20.7)		
Maid	6(10.7)	1(3.7)	5(17.2)		
Children	21(37.5)	10(37)	11(37.9)		
Other	3(5.4)	1(3.7)	2(6.9)		
Experience in smart device					0.598
< 0.5 year	8(14.3)	3(11.1)	5(17.2)		
1–2 years	8(14.3)	5(18.5)	3(10.3)		
> 2 years	40(71.4)	19(70.4)	21(72.4)		
MFAC	4.0(1.4)	4.3(1.0)	3.8(1.7)	0.173	
MBI	58.0(26.3)	65.1(20.7)	51.4(29.4)	0.048*	

Notes: Exp: experimental group; Con: control group; difference between groups by independent t-test or Chi-Square test.
$^*p < 0.05$.

Table 3. Exercise adherence and self-efficacy for exercise of experience and control groups.

	Groups: Baseline		Between-group	Groups: 1-Month		Between-group	Groups: 3-Month		Between-group
	Exp ($n = 27$)	Con ($n = 29$)	p-value	Exp ($n = 27$)	Con ($n = 29$)	p-value	Exp ($n = 27$)	Con ($n = 29$)	p-value
Adherence									
Mean (SD)	74.1 (24.4)	64.1 (34.0)	0.214	73.7 (21.5)	58.6 (37.3)	0.072	75.6 (26.2)	55.2 (35.8)	0.021*
SEE									
Mean (SD)	52.5 (15.2)	48.1 (16.7)	0.307	58.4 (11.7)	43.3 (20.0)	0.001*	62.2 (10.7)	45.6 (18.8)	< 0.000*

Notes: Exp: experimental group; Con: control group; difference between groups of Adherence by Chi-Square test; difference between groups of SEE by independent t-test.
*$p < 0.05$.

Table 4. Functional outcomes of experience and control groups.

	Groups: Baseline		Groups: 1-month		Groups: 3-month		Within-groups: 1-month gain (1-month minus baseline)		Between-group	Within-groups: 3-month gain (3-month minus baseline)		Between-group
	Exp ($n = 27$)	Con ($n = 29$)	Exp ($n = 27$)	Con ($n = 29$)	Exp ($n = 27$)	Con ($n = 29$)	Exp ($n = 27$)	Con ($n = 29$)	p-value	Exp ($n = 27$)	Con ($n = 29$)	p-value
MFAC												
Mean (SD)	4.3 (1.0)	3.8 (4.3)	5.1 (1.1)	4.3 (1.6)	6.0 (1.2)	4.8 (1.8)	0.9 (0.9)	0.5 (0.6)		1.7 (1.2)	1.0 (1.0)	
p-value							< 0.000*	< 0.000*	0.124	< 0.000*	< 0.000*	0.036*
MBI												
Mean (SD)	65.1 (20.7)	51.4 (29.4)	79.0 (15.6)	63.2 (30.0)	85.4 (17.3)	70.8 (29.0)	13.9 (12.0)	11.9 (8.4)		20.9 (13.9)	19.4 (13.1)	
p-value							< 0.000*	< 0.000*	0.474	< 0.000*	< 0.000*	0.808

Notes: Exp: experimental group; Con: control group; difference within groups by pair t-test; difference between groups by independent t-test.
*$p < 0.05$.

($p = 0.072$) but significant difference in 3 months adherence ($p = 0.021$) (Table 3).

There were significant between-group difference in 1 month change of SEE ($p = 0.001$) and 3 month change in SEE ($p < 0.000$). There were no between-group difference in 1 month change of MFAC but significant between-group difference in 3 month change of MFAC ($p = 0.036$). There were no between-group difference in 1 month change of MBI ($p = 0.474$) and 3 month change in MBI ($p = 0.808$) (Table 4).

Discussion

The main finding of the study was that mobile video-guided home exercise program was superior to standard paper-based home exercise programs in terms of exercise adherence, SEE and mobility gain but not basic ADL gain for patients recovering from stroke. This finding contrasted to the study of Emmerson *et al.* which showed that home exercise programs filmed on an electronic tablet was not superior to standard paper-based home exercise programs in terms of adherence, motor function, or satisfaction for patients recovering from stroke.[12] There are several possible explanations for these finding, the adherence of home exercise may depend on the type of exercise and interest of patients. It was suggested that mobility decline is an essential concern in chronic stroke patients.[42] Emmerson's study[12] only provided upper limb exercises that patients may have less interest to participate than the exercises in this study which consisted for arm, leg, trunk and mobility. We also found that there was a close relationship between exercise adherence and SEE. During the 3 months follow-up period, the SEE slightly increased (from 52.5 to 62.2 in video group) with the exercise adherence (from 74.1% to 75.6%) in experimental group; whereas the SEE was slightly decreased (from 48.1 to 45.6) with exercise adherence (from 64.1% to 55.2%) in control group (Table 3). The present results echoed with the theory of self-efficacy, the stronger the individual's self-efficacy, the more likely it is that people will initiate and persist with a given activity[16,45] that SEE was positive proportion to exercise adherence in both groups. The study also found that video-guided home exercise program could improve exercise adherence and SEE even without any regular encouragement, or automated reminder as in previous studies by Lambert *et al.*[13] and Emmerson *et al.*[12] The higher mobility gain of patients in experimental group than control group could be explained by adherence of home exercise program that has positive correlation with physical function and physical performance of patients.[28,29] No difference in MBI gain in experimental group when compared to control group means the video-guided exercise program improves mobility or ambulation (as measured by MFAC) but its effects could not be translated to improvement of ADL (as measured by MBI). This could be explained by specificity principle[46] that in training the home exercise program in this study was motor control and mobility orientated but not ADL orientated.

The limitation of the study included information bias introduced by outcome collection by telephone interview; selection bias to Chinese population since all the videos and pamphlets were in Chinese; and confounding bias by confounding variables such as, by chance, the experimental group had significant higher baseline MBI than that of control group. However, the effects of the confounding bias have been minimized by randomization and statistical analysis. The intervention fidelity monitoring is another limitation of the study; a pre-discharge training session was used to minimize the limitation. Further research studies with large sample size would allow comparing the most effective groups of the video-guided home exercise. In addition, as mentioned in the introduction session, it seems that adherence was affected by both self-efficacy and delivery mode of training program. The relationship between self-efficacy and delivery mode of training program such as video-guided element is still unclear and needs further study.

Conclusion

The use of mobile video-guided home exercise program was superior to standard paper-based home exercise program in exercise adherence, SEE and mobility gain but not basic ADL gain for patients recovering from stroke.

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this paper.

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Author Contributions

(1) Bryan Ping Ho Chung: Specifying the question, designing the study, analyzing the data, collecting and handling data, interpreting the data, writing — lead authorship.
(2) Wendy Kam Ha Chiang: Specifying the question, designing the study, collecting and handling data, interpreting the data, writing — contributing significant text.
(3) Herman Lau: Specifying the question, designing the study.
(4) Titanic Fuk On Lau: Specifying the question, translating a protocol into practice.
(5) Charles Wai Kin Lai: Translation of protocol into practice.
(6) Claudia Sin Yi Sit: Identifying data needed, identifying relevant references.
(7) Ka Yan Chan: Translation of protocol into practice.
(8) Chau Yee Yeung: Translation of protocol into practice.
(9) Tak Man Lo: Translation of protocol into practice.
(10) Elsie Hui: Translation of protocol into practice, reading, editing, checking.
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