Do mobility exercises in different environments have different effects in ankylosing spondylitis?

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ABSTRACT

Aims: Ankylosing spondylitis (AS) reduces spinal mobility, which results in structural and functional impairments. Pulmonary problems eventually occur in most AS patients due to interstitial lung disease or as a result of chest wall abnormalities. The aim of this study was to evaluate the effects on pulmonary functions and disease related scales of aquatic and land-based multidimensional functional mobility exercises on pulmonary functions in patients with AS.

Methods: In this randomized controlled study, 57 patients with definite AS according to the modified New York criteria were randomly allocated to an aquatic (AG), land-based (LG), or home (HG) exercise group and performed multidimensional mobility exercise sessions twice a week for 8 weeks. The Bath indices were used to measure disease activity, functional limitation, and spinal mobility, and a 10-cm visual analog scale assessed pain during activity and at rest. Pulmonary function tests, maximal inspiratory mouth pressure (MIP), and maximal expiratory mouth pressure (MEP) were measured before and after the intervention. The study is registered at ClinicalTrials.gov, number NCT03667625 (27/08/2018).

Results: Forty-six patients (30.4% female) with a mean age of 42.0 years completed the study. Multidimensional exercises improved disease-related symptoms such as pain, spinal mobility, and functionality, but there were no significant changes in HG. Patients in AG showed significant improvements in peak expiratory flow (p=0.004), vital capacity (p=0.025), maximum voluntary ventilation (p=0.006), and MIP (p=0.001), while those in LG showed significant increases in forced expiratory volume during the first second to forced vital capacity (FEV1/FVC) ratio (p=0.049), peak expiratory flow (p=0.007), and maximum voluntary ventilation (p=0.004). There were no significant changes in HG.

Conclusions: Multidimensional functional mobility exercises performed either in water or on land are important in the management of pulmonary manifestations of AS.

Keywords: Hydrotherapy; Respiratory Function Tests; Ankylosing spondylitis.

INTRODUCTION

Ankylosing spondylitis (AS) is a chronic inflammatory disease that mainly affects the sacroiliac joint and axial skeleton. AS is characterized by inflammation followed by bone formation, thought the etiology of the disease remains unclear. Progressive mobility reduction, postural deformities and gait repercussions are the most common burden of the AS[1]. The main focus of AS management was used to be on axial skeleton however almost 40% of the patients suffer from at least one extra-articular manifestation[2]. Pulmonary manifestations of AS could be asymptomatic yet respiratory diseases are the third common cause of death among AS[3]. Chest wall restriction, natural disease course, and medication side effects can cause pulmonary manifestations such as fibrosis of the upper lobes, interstitial lung disease, spontaneous pneumothorax, mycetoma associated with secondary infections, emphysema, bronchiectasis, and ventilatory impairment[4-7]. Exercise therapy plays an essential role in the management of both articular and extra-articular manifestations of AS[8-13]. However, studies investigating the pulmonary effects of exercise therapy are scarce and inconsistent[11, 14-17].

Berdal et al reported that restrictive ventilatory impairment is related to reduced spinal mobility rather than disease activity, physical function or oxygen uptake peak (VO2peak)[5]. Stretching exercises are one of

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the most common types of exercises targeting restricted spinal and thoracic movements in AS. Unidirectional trunk and limb stretches were used in most of the related studies in the literature[16,18-21]. However, multidimensional exercises are based on the concept that muscles and extra-articular structures are connected to each other and move together, so strengthening and flexibility exercises should focus on functional and structural chains rather than a single movement[22]. Therefore, multidimensional exercises could be more effective for patients with global movement restrictions like in AS[9]. Recent studies have included multidimensional stretching exercises such as Global Postural Reeducation (GPR), but this type of exercise requires static stretches for extended periods of time, such as 20 minutes[17, 23, 24]. Related literature expresses that chest and spinal mobility exercises are crucial to maintain pulmonary functions in AS[25, 26].

Water provides a unique environment for rheumatology patients. The warm temperature and freedom of movement seem to have additional therapeutic effects on pain, disease activity, and spinal range of motion in patients with AS[27-29]. Thermal effects of water have been used to treat rheumatologic disorders since ancient times. With the understanding of the importance of exercise in modern times, such passive practices have been refrained; however recently, the combined use of these two modalities has become more popular. Studies showed that aquatic exercises have similar effects of passive immersion baths and land exercise also has an advantage for cases where land therapy is not well tolerated[30]. The fluid mechanics of water alter pulmonary function, increase the workload of breathing, and change respiratory dynamics, and thus add a therapeutic feature[31-33]. Performing multidimensional exercises in water decreases the effect of gravity and friction, resulting in expanded range of motion[34, 35]. In addition, increasing breathing workload has an impact on pulmonary functions[36]. Studies presented that aquatic interventions provide additional benefits for pulmonary functions in different conditions[37, 38]. The literature about pulmonary effects of aquatic therapy in AS is lacking. One study showed that water based and land based aerobic exercises had similar pulmonary affects[39] and the other one concluded that passive balneotherapy did not affect pulmonary functions in AS[10]. As mentioned before pulmonary manifestations mainly due to musculoskeletal restrictions of spine[25, 26]. There is not enough evidence on the pulmonary effect of land and water based spinal mobility exercise in AS.

To our knowledge, no study has previously compared the effects of multidimensional functional mobility exercise in different environments in AS patients. The aim of this study was to evaluate the effects of aquatic and land-based multidimensional functional mobility exercises on pulmonary functions and disease related scales in AS patients.

MATERIALS AND METHODS

A total of 57 patients with definite AS according to the modified New York criteria[29] were recruited for the study from the internal medicine department, rheumatology division of a university hospital in Turkey. The number of participants was calculated with GPower (version 3.0.10) according to the results of a similar study[24]. Bath Ankylosing Spondylitis Functional Index (BASFI) score, in which clinically significant change was shown in this study, was 0.66, to have 80% power with 5%type I error level (1:1 the control versus intervention ratio) the minimum required sample size was calculated as 16. To allow for potential dropouts reported in a similar study[39], 3 more patients were included in each group, resulting in 19 patients allocated to each treatment group.

Demographic data including age, gender, body mass index (BMI), duration of symptoms, physical activity, and smoking status were recorded at initial interview. Patients who participated in any physical exercise program within the 3 months prior to this study and those diagnosed with any cardiovascular, respiratory disease or other neuromuscular disease that may affect the respiratory muscles were excluded. Patients who developed any acute condition requiring a change in treatment and patients who missed 4 or more sessions were classified as dropouts. The patients were randomly assigned into aquatic (AG), land-based (LG), and home (HG) exercise groups by using random numbers table. Patients were given numbers according to their allocation time. A random spot was picked from the table as the starting point.Two digit numbers were created by following the table. The numbers that fall in the range were allocated as AG, LG, and HG respectively.

The patients were informed of the purpose of the study and provided written informed consent before inclusion. The study protocol was approved by a local ethics committee in Turkey (Approval No. 2016/06-41). This study is registered with ClinicalTrials.gov, number NCT03667625.

EXERCISE PROTOCOL

Aquatic group (AG):

Aquatic multidimensional mobility exercises were performed in the treatment pool at Balcova Thermal Centre in Izmir, Turkey. Groups of 6–7 patients were instructed by a physiotherapy specialist twice a week for 8 weeks. The water temperature was 33–34°C and the depth was 110–140 cm. Patients were asked to maintain T11-level submersion during vertical exercises. Exercise duration was 30–40 min in the first 4 weeks, then increased to 45–50 min with additional exercises. Appendix I

Land-based group (LG):

Multidimensional mobility exercises were conducted in the exercise unit of a physical therapy school. Groups of 6–7 patients were instructed by a physiotherapy specialist twice a week for 8 weeks. The room temperature was 23–24°C. Exercise duration was 30–40 min for the first 4 weeks, then increased to 45–50 min with additional exercises. Appendix II

Home exercise group (HG):

Patients in this group were provided instruction on the mobility exercises recommended in common patient information handouts by a physiotherapist in the outpatient clinic after the initial evaluation. The physiotherapist contacted patients weekly by phone to ensure compliance with the exercise program. Appendix III

CLINICAL ASSESSMENTS

Baseline assessments were performed in three days before the interventions, the final assessments were performed in the next day of the final intervention session initial and last assessments were performed at the same conditions. Assessors were blinded to intervention group.

Pulmonary functions and muscle strength values were discussed as primary outcome.

Pulmonary function tests (PFT): PFT were performed with patients seated using a portable spirometer (MiniSpir, Rome, Italy) according to the criteria recommended by the American Thoracic Society and European Respiratory Society[40]. Vital capacity (VC), forced vital capacity (FVC), forced expiratory volume during the first second (FEV1), FEV1/FVC ratio, peak expiratory flow (PEF), and maximum voluntary ventilation (MVV) were tested three times for each participant and the best performance was recorded. Along with the observed values, the parameters of the pulmonary function test were compared with the predictive normative values for age, height, body weight, gender and race, and were shown as% of the predictive value. The reference values recorded in the system of the spirometer device were used to give the% of the measured values according to the predictive values.

Respiratory muscle strength: Strength of the diaphragm and other inspiratory muscles was measured with maximal inspiratory pressure (MIP), while strength of the abdominal muscles and other expiratory muscles was measured with maximal expiratory pressure (MEP). Patients were asked to perform maximal inspiratory and expiratory effort against a closed system, a digital manometer (Micro RPM, Micro Medical Ltd, Kent, UK), while sitting. A nose clip was used to prevent air leakage. The tests were repeated three times for each participant and the best MIP and MEP were recorded. The data were expressed as percentage of predicted value. Higher value indicates greater muscle strength[41].

Disease related scales: The Bath indices were used to measure disease activity, functional limitation and spinal mobility. The Bath indices were widely used patient-reported measurement tools. These indices have good discrimination between groups and interventions[42]. The Bath indices were the secondary outcome of the study.

The Bath Ankylosing Spondylitis Functional Index (BASFI); a ten questioned self-administrative questionnaire about their degree of functional limitation was given to the patient. The higher the BASFI score represents more limited patient[42].

The Bath Ankylosing Spondylitis Disease Activity Index (BASDAI) has 6 questions on fatigue, spinal pain, joint pain/swelling, areas of localized tenderness, morning stiffness. Patient was asked to mark on a 10 cm visual analog scale (VAS). The higher the BASDAI score the more severe the disease activity[42].

Bath Ankylosing Spondylitis Metrology Index (BASMI); cervical rotation, tragus to wall distance, lumbar side flexion, modified Schober Test and intermalleolar distance were measured by an experienced physiotherapist. The score of each measurement was converted into a nominal score between 0 and 10. The higher the BASMI score the more severe the patient's spinal limitation[42].

Pain: The pain level at rest and at activity was measured by VAS. Patients were asked to mark their recent paint level on a 10 cm VAS. The higher the VAS score the more severe the patient's pain[43].

STATISTICAL ANALYSIS

All statistical analyses were performed using SPSS version 22 for Windows. Descriptive data were presented as median and quartiles. The Shapiro–Wilk test was used to analyse whether quantitative variables conformed to normal distribution. Nonparametric tests were used for statistical analysis since not all of the data (BASMI, PFT) were normally distributed. Baseline demographic and clinical characteristics were compared using the nonparametric Mann–Whitney U test. Wilcoxon's signed rank test was used for intragroup comparisons, while Mann–Whitney U test was used for comparisons of improvement (difference between pre- and post-intervention scores) between groups. A p value less than 0.05 was considered statistically significant. Significant results were then analysed by post-hoc tests (Wilcoxon signed ranks test with Bonferroni correction) in which the significance level was set at 0.017 (0.05/3) after Bonferroni correction. The confounding effect of independent (age, gender, BMI, disease duration, medication, or smoking status) variable was assessed using a repeated measures analysis of variance (RMANOVA).

RESULTS

Forty-six patients completed the study. Three patients from AG and 6 from LG missed 4 consecutive sessions and 2 HG patients did not attend the last evaluation. Demographic data of the study group are summarized in Table I. There were no statistically significant differences in age, gender, BMI, disease duration, medication, or smoking status between the groups ($p>0.05$). The RMANOVA test revealed that age, gender, BMI, disease duration, medication, or smoking status had no statistically significant effect on results of intervention groups ($p>0.05$).

PFT parameters significantly improved in both of

TABLE I. DEMOGRAPHIC AND DISEASE CHARACTERISTICS OF THE GROUPS AT BASELINE

	Aquatic Group (n=16) Median (Interquartile Range)	Land Group (n=13) Median (Interquartile Range)	Home Group (n=17) Median (Interquartile Range)
Age (years)	43.0 (38.3/47.8)	43.0 (37.0/47.5)	40.0 (32.0/44.0)
BASDAI	3.1 (1.7/4.5)	2.4 (1.9/4.7)	4.2 (1.3/5.05)
BASFI	2.5 (1.1/4.8)	1.7 (0.2/2.2)	2.3 (1.1/4.2)
BASMI	11.5 (6.0/24.3)	9.0 (6.5/12.0)	13.0 (7.5/2.0)
Pain (VAS) cm	2.2 (1.0/3.8)	2.5 (0.8/4.0)	3.0 (1.6/5.75)
Disease Duration (years)	6.5 (3.3/12.8)	2 (2.0/16.5)	2 (1.0/13.0)
	n (%)	**n (%)**	**n (%)**
Gender			
Female	3 (18.8)	6 (46.2)	5 (29.4)
Male	13 (81.8)	7 (53.8)	12 (70.6)
Smoking			
Non-smoker	3 (18.8)	5 (38.5)	8 (47.1)
Smoker	5 (31.2)	1 (7.7)	6 (35.3)
Ex-smoker	8 (50.0)	7 (53.8)	3 (17.6)
Medication			
None	3 (18.8)	2 (15.4)	1(5.6)
NSAIDs	3 (18.8)	6 (46.2)	8 (47.1)
DMARDS	6 (37.5)	4 (30.8)	4 (23.5)
Anti-TNF	4 (25.5)	1 (7.7)	4 (23.5)

BMI: Body Mass Index; BASDAI: Bath Ankylosing Spondylosis Disease Index; VAS: Visual Analog Scale; BASMI: Bath Ankylosing Spondylosis Metrology Index;BASFI: Bath Ankylosing Spondylitis Functional Index; NSAIDs: nonsteroidal anti-inflammatory drugs; DMARDS: Disease-Modifying Anti-rheumatic Drugs the multidimensional stretching groups after the intervention (Table II). Patients in AG showed significant improvements in PEF (p=0.004), VC (p=0.025), MVV (p=0.006), and MIP (p=0.001) and those in LG showed significant increases in PEF (p=0.007), and MVV (p=0.004) after the 8-week multidimensional functional mobility exercise program (Table II). However, there were no significant changes in HG. Table III shows the results of intergroup comparisons.

MVV and PEF improved in both AG and LG with no significant differences in intergroup comparison, but no change was observed in FEV1/FVC, FEV1 or FVC in either group after the 8-week intervention.

Significant increases in MIP and MEP were seen in AG but not in LG (Table II). The intergroup comparison also showed statistically significant differences between the groups for FEV1/FVC (p=0.025), MVV (p=0.001), MIP (p=0.001) and MEP (p=0.001) (Table II).

Data regarding FEV1/FVC values were contradictory. None of the groups showed statistically significant improvement. Intergroup comparison revealed statistically significant difference between delta values in favour of AG. In AG, FEV1/FVC ratio increased after the intervention but not significantly (p=0.105) (Table II).

Only AG showed significant post-intervention improvement in VC. However, there was no statistically significant difference in intergroup comparison (p=0.650) (Table II).

The results showed BASMI and BASDAI scores improved in both AG and LG no significant differences in intergroup comparison. BASFI score showed statistically significant increase in AG but not in LG and HG (Table III).

There was a statistically significant improvement in pain levels in both of themultidimensional stretching groups after the intervention (Table III). The intergroup comparisons indicated that improvement in pain level of AG at rest and at activity was higher than HG, where-

TABLE II. INTERGROUP COMPARISON OF THE INITIAL AND LAST ASSESSMENT DIFFERENCES OF DISEASE RELATED SCALES

	Aquatic Group (n=16) Median (Interquartile Range)		Land Group (n=13) Median (Interquartile Range)		Home Group (n=17) Median (Interquartile Range)		
	Before	After	Before	After	Before	After	p value
BASMI	11.5 (6.0/24.3)	6.5*a (1.3/22.0)	9.0 (6.5/12.0)	4.0*b (4.0/5.5)	13.0 (7.5/20.0)	14.0 (7.5/19.5)	
Δ	-4.5 (-6.0/-3.0)		-3.0 (-5.5/-2.0)		0.0 (0.0/2.2)		p<0.001#
BASDAI	3.1 (1.7/4.9)	0.6* (0.1/1.3)	2.4 (1.9/4.7)	0.6*b (0.5/1.9)	4.2 (1.3/5.1)	4.2 (1.4/5.0)	
Δ	-2.5 (-3.8/ -1.5)		-1.6 (-3.0/-0.7)		0.0 (0.0/0.3)		p<0.001#
BASFI	2.5 (1.1/4.8)	0.3*a (0.0/1.2)	1.7 (0.2/2.2)	0.1 (0.0/2.4)	2.3 (1.1/4.2)	3.4 (1.3/5.8)	
Δ	-2.0 (-3.1/-0.7)		-0.2 (-1.1/0.2)		0.0 (-0.1/0.6)		p<0.001#
VAS (rest)	2.2 (1.0/3.8)	1.0*a (0.0/1.5)	2.5 (0.8/4.0)	1.0*b (0.0/2.5)	3.0 (1.6/5.8)	4.0 (1.8/5.8)	
Δ	-1.0 (-2.6/ -2.0)		-1.0 (-2.3/0.0)		-0.3 (0.0/0.9)		0.01#
VAS (act)	2.8 (1.5/6.8)	0.4*a (0.0/1.5)	1.5 (0.9/4.3)	1.0* (0.0/2.3)	3.0 (1.3/5.5)	3.5 (0.9/5.0)	
Δ	-1.3 (-4.7/-0.8)		-1.0 (-1.8/0.0)		0.0 (-0.4/1.0)		0.03#

BASDAI: Bath Ankylosing Spondylosis Disease Index; VAS: Visual Analog Scale; BASMI: Bath Ankylosing Spondylosis Metrology Index; BASFI: Bath Ankylosing Spondylitis Functional Index
Kruskal Wallis Test #p<0.05
Wilcoxon Signed Rank Test *p<0.05 within groups;
a-c (post-hoc Mann–Whitney U test between groups test with Bonferroni correction resulting in a significance level of p< 0.017);
a Aquatic versus land; b Land versus home; c Aquatic versus home

TABLE III. INTERGROUP COMPARISON OF THE INITIAL AND LAST ASSESSMENT DIFFERENCES OF PULMONARY FUNCTION PARAMETERS

	Aquatic Group (n=16) Median (Interquartile Range)		Land Group (n=13) Median (Interquartile Range)		Home Group (n=17) Median (Interquartile Range)		
	Before	After	Before	After	Before	After	p value
FVC (lt)	3.9 (3.3/4.7)	4.3 (3.3/4.7)	3.7 (3.2/5.0)	3.8 (3.1/4.8)	3.5 (3.0/4.1)	3.2 (3.0/4.0)	
Δ	0.1 (-0.1/2.0)		0.1 (-0.1/0.2)		-0.1 (-0.3/0.1)		0.065
FEV1 (lt)	3.1 (2.8/3.9)	3.4 (2.7/3.8)	3.2 (2.7/4.1)	3.2 (2.6/4.1)	3.1 (2.5/3.5)	3.0 (2.6/3.7)	
	0.1 (-0.2/0.3)		0.0 (-0.1/0.1)		0.0 (-0.10.1)		0.878
FEV1/ FVC (lt)	78.3 (76.5/80.6)	81.8[a] (77.4/86.6)	84.7 (81.8/89.2)	85.3 (81.0/87.5)	83.2 (78.4/87.2)	84.6 (81.1/88.3)	
Δ	2.7 (-0.1/4.8)		-1.1 (-3.8/0.7)		0.0 (-1.4/3.3)		0.025#
PEF (lt)	7.4 (5.8/8.6)	8.2* (6.8/9.8)	6.8 (5.1/8.3)	7.7* (5.9/10.1)	7.4 (5.6/9.2)	7.0 (5.5/8.6)	
Δ	1.0 (-0.1/2.3)		0.9 (0.0/1.7)		0.0 (-0.9/0.5)		0.051
VC (lt)	4.9 (4.0/6.5)	6.0* (4.4/6.9)	5.6 (3.9/6.3)	5.3 (4.5/6.4)	4.3 (3.8/5.7)	4.6 (4.2/5.5)	
Δ	0.4 (-0.1/1.4)		0.0 (-0.7/1.6)		0.1 (-0.2/0.6)		0.434
MVV (lt)	114.1 (106.7/137.7)	126.6*[c] (113.3/165.2)	115.2 (91.8/139.3)	146.5*[b] (95.6/164.0)	118.8 (105.3/131.7)	112.0 (93.2/133.4)	
Δ	17.4 (7.6/22.9)		18.9 (5.2/35.7)		-3.7 (-15.0/0.8)		p<0.001#
MIP (cm H2O)	86.5 (61.3/117.5)	113.0*[a c] (66.0/135.0)	112.0 (76.0/125.0)	107.0 (77.0/137.5)	83.0 (73.5/104.0)	82.0 (60.5/101.5)	
Δ	13.5 (6.3/27.0)		4.0 (-10.0/10.5)		-4.0 (-8.0/0.5)		p<0.001#
MEP (cm H2O)	161.0 (139.8/186.8)	141.5*[a c] (89.0/161.5)	128.0 (119.0/185.5)	130.0 (111.0/173.5)	109.0 (100.0/145.0)	111.0 (106.5/147.5)	
Δ	25.0 (8.3/42.3)		6.0 (0.0/16.0)		-2.0 (-8.5/3.5)		p<0.001#

Kruskal Wallis Test #p<0.05
Wilcoxon Signed Rank Test *p<0.05within groups;
a-c (post-hoc Mann–Whitney U test between groups test with Bonferroni correction resulting in a significance level of p< 0.017)
a Aquatic versus land
b Land versus home
c Aquatic versus home
FVC: forced expiratory vital capacity; FEV1: forced expiratory volume during the first second; FEV1/FVC: forced vital capacity ratio of forced expiratory volume during the first second; PEF: peak expiratory flow rate; VC: vital capacity; MVV: maximum voluntary ventilation; MIP: maximum inspiratory pressure; MEP: maximum expiratory pressure.

as in only LG pain level at rest was statistically significantly different then HG.

DISCUSSION

This controlled study was conducted to evaluate the effects of mobility exercises performed in two different environments on pulmonary functions and disease related scales in AS. To our knowledge, this is the first study focusing on the pulmonary effects of land-based multidimensional mobility exercises. There was no adverse effect reported by any of the participants.

None of the patients in the study experienced or showed any sign of pulmonary problems, and PFT results were within normative ranges according to the patients' age and sex[44]. Therefore, our intention in this study was not to treat symptoms, but to observe the pulmonary effects of multidimensional exercises in people with AS. The results of our study showed that the same multidimensional mobility exercises performed in different environments resulted in significant improvements in different pulmonary function parameters.

The pulmonary complications of AS have been known for many years, and exercise plays an important role in the treatment of AS and these pulmonary problems[9, 45-47]. Spinal restriction in AS highlights the importance of mobility and flexibility exercises. Even though stretching and flexibility exercises are the most common type of exercise used in the management of AS, there is limited evidence regarding the type, intensity, and duration of exercise. Likewise, aqua therapy is also a promising intervention for both spinal restriction and pulmonary problems, but the number of relevant studies is limited.

PEF and MVV values were shown to be significantly lower in AS patients compared to their healthy age- and sex-matched peers[48, 49]. PEF is an indicator of voluntary effort and muscle strength, while MVV is related to the endurance of the pulmonary muscles. Our study showed that multidimensional mobility exercises improved PEF and MVV in AS patients. Durmu *et al.* also reported improvement in PEF and MVV both in conventional exercise and GPR[17]. However, in another study, PEF value did not change in patients who participated in conventional exercise training with or without additional inspiratory muscle training[11].

There was no significant post-intervention difference in FEV1/FVC ratio in any groups. Karapolat *et al.* reported a similar result that FEV1/FVC ratio did not change with walking or swimming in AS[21]. However, another study showed that FEV1/FVC ratio increased in AS patients in a home-based exercise group compared to the control group[20]. On the other hand, comparison of FEV1/FVC ratio delta values showed that there was a statistically significant difference between the two groups of multidimensional mobility exercises in favour of AG. The initial FEV1/FVC ratio values of AG were significantly lower than LG group after the intervention the differences between these values were reduced. It is known that FEV

1/FVC ratio increases with aerobic exercise, but there is not yet enough evidence to compare the effects of land- and water-based mobility exercises on this parameter[50].

The total work of breathing at rest for a tidal volume of 1 litre increases by 60% when submersed to the neck[36]. Studies have shown that immersion causes reductions in MIP and VC but no change in MEP[51, 52]. This increase in workload may lead to pulmonary muscle strengthening, though no evidence of this has been presented in the literature to date. However, our study shows that aquatic mobility exercises improved pulmonary muscle strength and VC. There was significant improvement in MIP, MEP, and VC values in AG but not in LG. These changes may be attributable to resistance on the pulmonary muscles due to the increased breathing workload or to the expanded range of motion achieved in water due to the reduced effect of gravity and friction. AG scores showed improvement in functionality, similar to MIP and MEP. It is very difficult to come to a conclusion from this study that respiratory muscle strength and BASFI were related, but we can state that aquatic exercises had greater effect on respiratory muscle strength and functionality.

The results of the study presented that multidimensional exercises improved disease related symptoms such as pain, spinal mobility, functionality. There was significant improvement in BASMI, BASDAI and pain scores in AG and LG after 8 weeks of intervention but not in HG. There was no statistically significant change in BASFI score of LG where AG scores showed improvement in functionality. Additionally, AG had greater improvement in BASMI, BASFI and pain level at rest and in activity. Dundar *et al.* reported that pain levels and quality of life score improved better in AG then HG[53] where Karapolat *et al.* found no difference between swimming and walking group regarding pain and disease related indices. Warm water immersion has an effect on pain[54], the former study and this study warm water was used unlike Karapolat's intervention was in cooler temperature thus using warm water may have an effect on pain relief. Kubo *et al.*[55] demonstrated in their in vivo study that the response to stretching of the gastrocnemius tendon, immersed in hot or cold water prior to stretching, was not different. Therefore, the difference in BASMI scores could be related to effectiveness of the water environment in the treatment is to eliminate gravity and allow different exercise positions.

HG showed no change in BASMI, BASDAI, BASFI and pain scores. The literature in AS about home exercises are contradictory some studies reported beneficial effects[17] where in some studies no change occurred[39, 56]. It is difficult to compare the effectiveness of home based programs from the existing literature due to the lack of home based exercise details. HG exercises were different than supervised LG exercises in this study. Different exercises were expected to have different results. It is a commonly accepted fact that supervised exercises are superior to home exercises[57, 58]. The reason for unchanged scores of BASMI, BASDAI, BASFI and pain in HG could be cultural (not being used to exercise) or personal (fail to practice properly, lack of commitment to exercise program).

To our knowledge, this study is the only research concerning pulmonary changes after mobility exercises in different environments; therefore, it is difficult to discuss the mechanisms underlying these results.

This study is the first study that investigates the results of the multidimensional mobility exercises conducted on land and in water therefore adds scientific value to the current evidence. However, there are some limitations should be highlighted. Firstly, the data about long-term effect is missing a follow up measurement is recommended for the future researches. Secondly, different exercises environments may have different effect on anti-inflammatory markers, quality of life and quality of sleep that were not included in the current study. Lastly, this study did not include AS patients with pulmonary involvements therefore, it is difficult to conclude that multidimensional mobility exercises on land and in water are suitable for AS patients with pulmonary problems.

In conclusion, pulmonary functions may be affected in AS patients, and multidimensional functional mobility exercises may have a therapeutic effect on pulmonary function and disease symptoms. Performing these exercises in water and on land may yield different results. Aquatic exercise could have additional benefits such as increasing inspiratory muscle strength and functionality.

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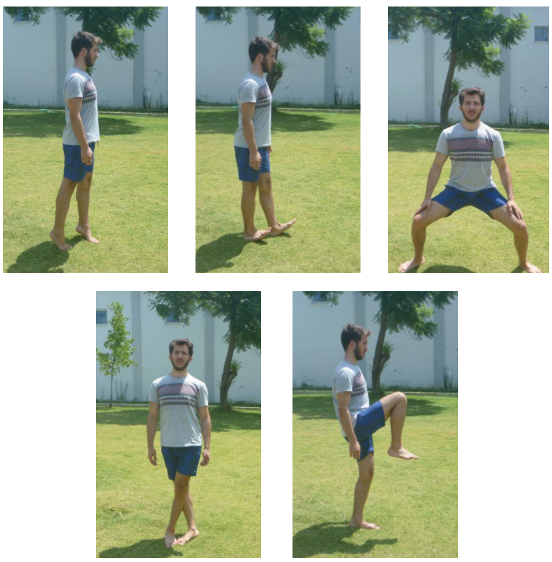
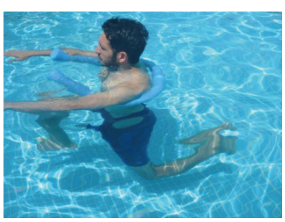
APPENDIX I

1-4. WEEK AQUATIC EXERCISES
WARM UP

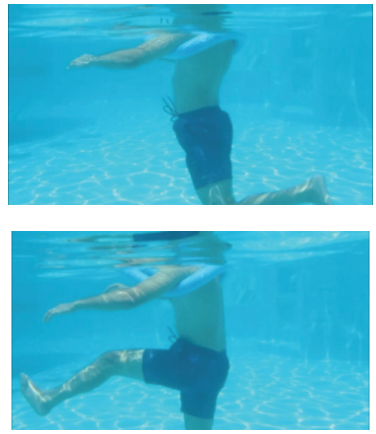
1. First 8 exercises of land exercise warm up session



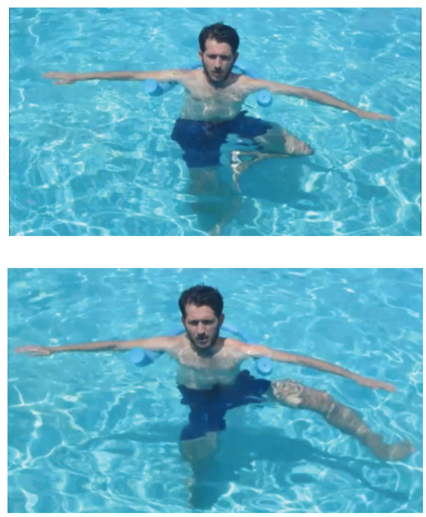
2. Walking with higher knees, on toes, on heels and to sides (30 m. each)



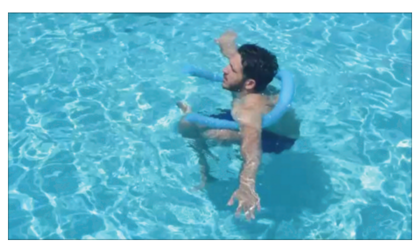
Follwing 4 exercises performed in a circut. During circut noodle was kept under arms. Circut repeated 3 times for each sides



3. Circle on the sagittal plane with right leg, maintain left leg position 3 times

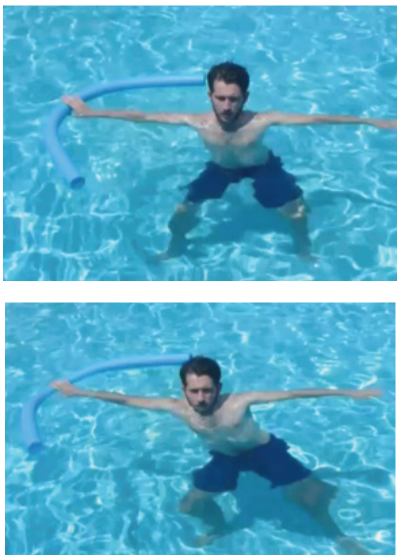


4. Circle on the coronal plane with right leg; maintain left leg position 3 times



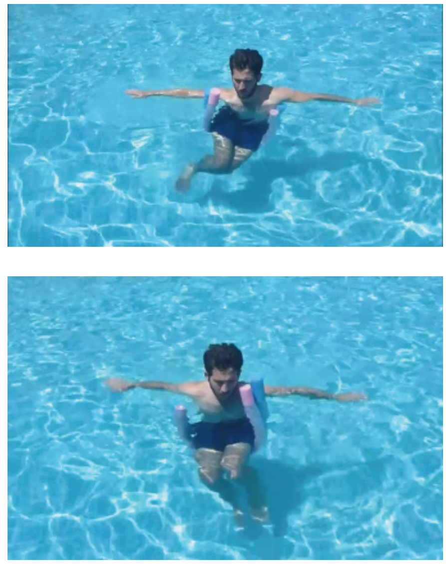
5. Place right foot on left knee, flex left hip and stretch right hip maintain 15 sec.

6. Place right foot on left knee, push left leg to hyper extension, left hip flexors maintain 15 sec.



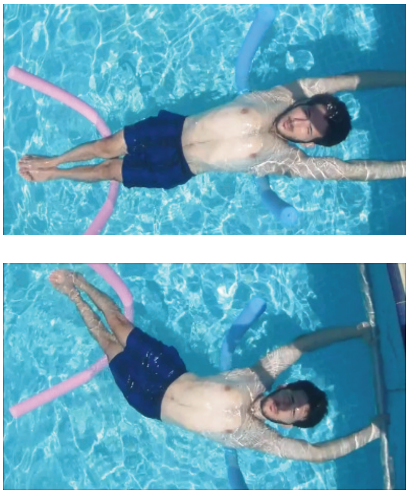
7. Stand with leg apart and hold the noodle in right arm. Flexing right knee push the noodle as far as possible on coronal plane maintain 15 sec. Repeat 3 times for each sides

8. Sit on the noodle with bended knees lift right arm to 1800 flexion (right hip sinks due to metacentric affect). Take a deep breath and repeat 8 times for each sides

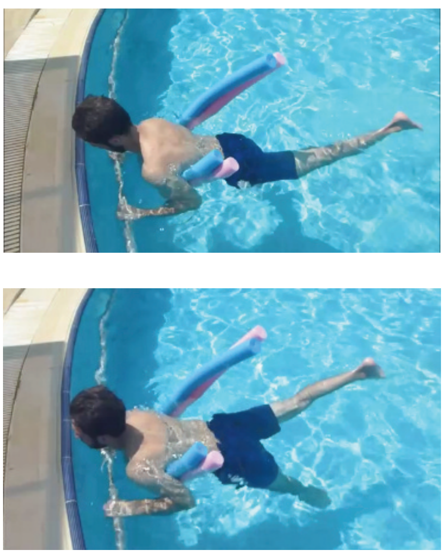


9. Sit on the noodle with bended knees and spread arms. Elevate right hip and left hip consecutively. 8 times for each side

10. Sit on the noodle with bended knees, arms 900 flexed, rotate head and lower trunk right while rotate arms and upper trunk to left. Take a deep breath and repeat for the other side. 8 times for each sides



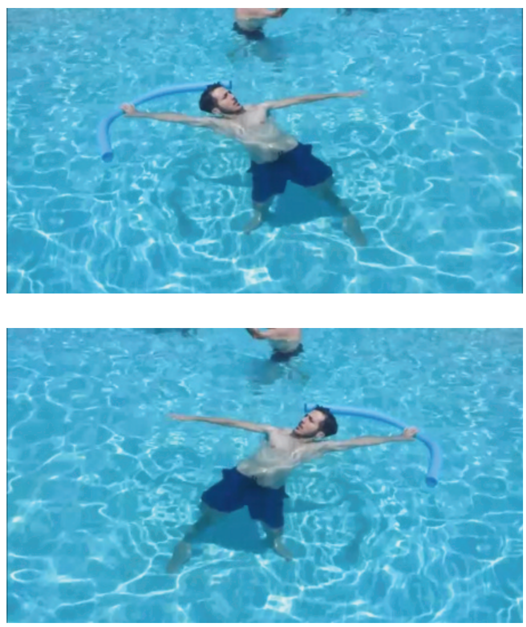
10. Supine lying with noodle under knees and under T11. Hold the bar with extended arms. Laterally flex the trunk (try not to engage arms. Movement should initiate with trunk muscles). Take a deep breath and repeat for the other side. 8 times for each sides



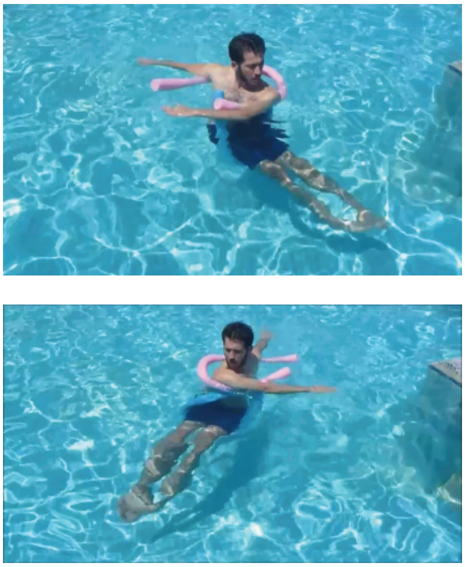
11. Prone lying with two noodles under arms and hold the bar with 900 flexed elbows. Tuck in the chin alternate bilateral flexion and extension of the hips with extended knees. 12 repetition

12. Supine lying with noodle under knees and under arms. Feet together external rotation of the hips. 900 abduction and external rotation of the arms. Keep chin tucked. Focus on inhale and exhale for 2 minutes

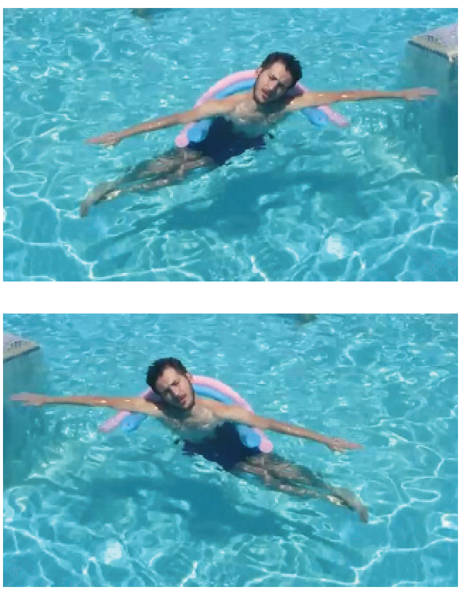
5-8. WEEK AQUATIC EXERCISES FOLLOWING EXERCISES WERE ADDED TO PREVIOUS PROGRAMME



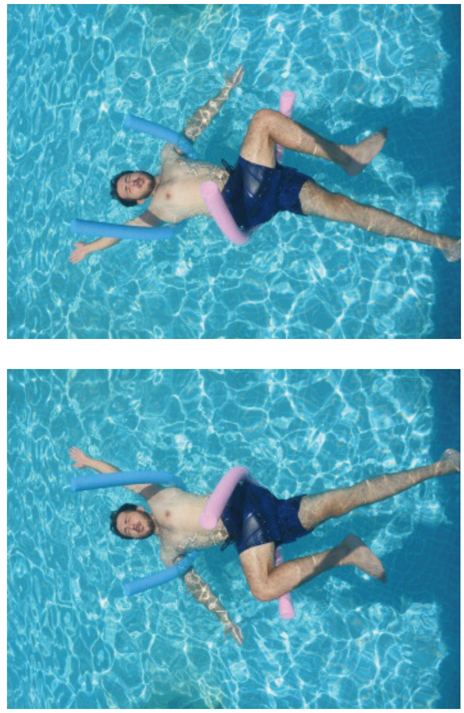
14. Stand with leg apart and hold the noodle in right arm. Flexing right knee push the noodle as far as possible to side flexion also rotate upper trunk and head contra laterally maintain 15 sec. Repeat 3 times for each sides.



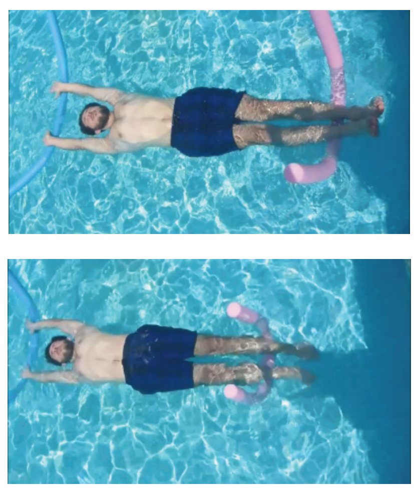
15. Sit on the noodle with extended knees, arms 900 flexed, rotate head and lower trunk right while rotate arms and upper trunk to left. Take a deep breath and repeat for the other side. 8 times for each sides



16. Sitting position with two noodles under arms 900 abduction of the arms. Lift both legs on right side to stretch left side of the body. Take a deep breath and repeat for the other side. 8 times for each side.



17. Supine lying with noodle under arms and under S2. Flex right knee and hip while rotating lower trunk contralaterally. Arms move due to metacentric effect. Take a deep breath and repeat for the other side. 8 times for each side.



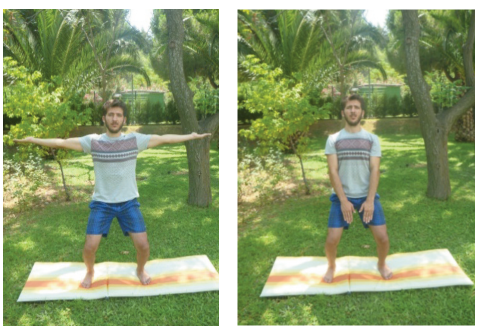
18. Supine lying with noodle under wrists and under calves. Push the noodles into the water ~ 3cm. Take a deep breath and repeat for 8 times.

APPENDIX II

1-4. WEEK LAND PROG
WARM UP

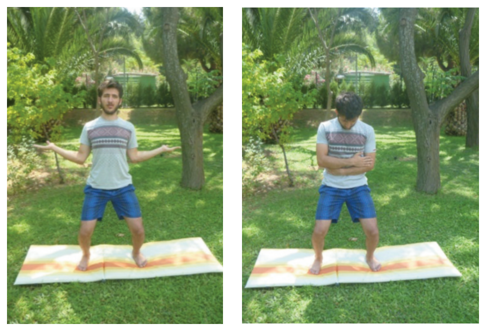
1. Bilateral internal & external rotation of the shoulders combined with breathing, 3 times

2. Bilateral flexion & extension of the shoulders combined with breathing, 3 times



3. Bilateral flexion-abduction-external rotation & extension- adduction- internal rotation combined with breathing, 3 times.

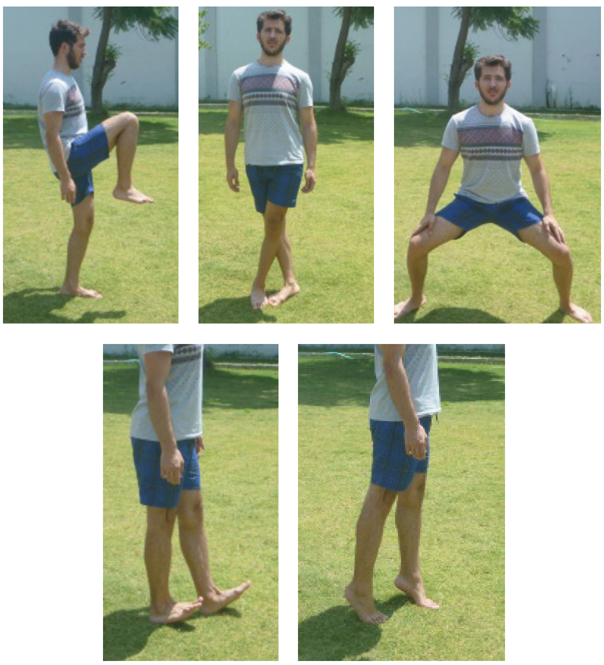
4. Bilateral horizontal abduction & adduction of the shoulders combined with breathing, 3 times



5. Bilateral internal & external rotation of the shoulders with bended elbows and arms by side combined with breathing, 3 times

6. Turn to right side, unilateral shoulder horizontal abduction and adduction combined with breathing, 3 times, repeat with other side(keep looking ahead)

7. Turn to right side, R horizontal abd
R horizontal add L horizontal abd
R horizontal add L horizontal abd
L horizontal add R horizontal abd
L horizontal add. 3 times, repeat with other side (keep looking moving hand)



8. Walking with higher knees, on toes, on heels and to sides (30 m. each)

MAIN PROGRAM

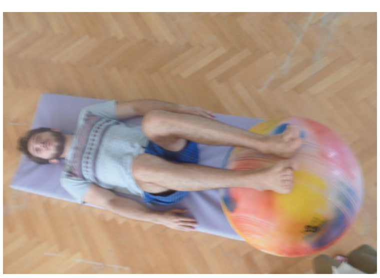
9. Walking with extended arms and knees 20 m

10. Walking backwards pushing bended knee downwards and lifting contralateral arm upwards. Stay, inhale, and exhale as stepping back. (20 steps)

11. Roll up the exercise ball hold for 15 sec and roll back to 900 shoulder flexion, repeat 3 times

12. Sitting on the knees, holding the exercise ball with stretched out arms. Rotate upper trunk right holds for 15 sec turn to starting position, same for the left side.
(repeat 3 times)

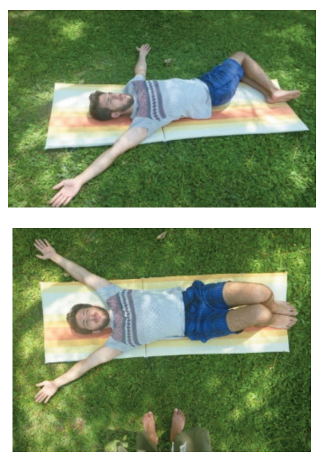
13. Supine hook lying position. One heel on the exercise ball roll in & out the leg 15 times, same for the other leg.



14. Supine hook lying position. Both knees on the exercise ball maintain leg positions and circle legs for 15 times both clockwise and counter clockwise.

Place TheraBand Flexbar between scapula for exercise 15 and 16. (individuals' best fitted colour)

15. Supine hook lying position. One heel on the exercise ball roll in & out the leg 15 times, same for the other leg.



16. Supine hook lying position with arms 1800 flexion- 1200 abd, bend both knees a sides add ipsilateral arm 900 deep breath return to starting position for the other side. Stay for 15 sec at 7th repetition at both sides.

17. Long sitting position TheraBand Strectch Strap was fixed to toes. Full plantar flexion, stretch the strap with arms. Slow dorsi-flexion against the stretched strap for 15 sec. Repeat 3 times for each sides

18. Place TheraBand Flexbar under right hip, cross right foot on bended left knee. Support with the hands move back and forth 8 times. Repeat with the other side

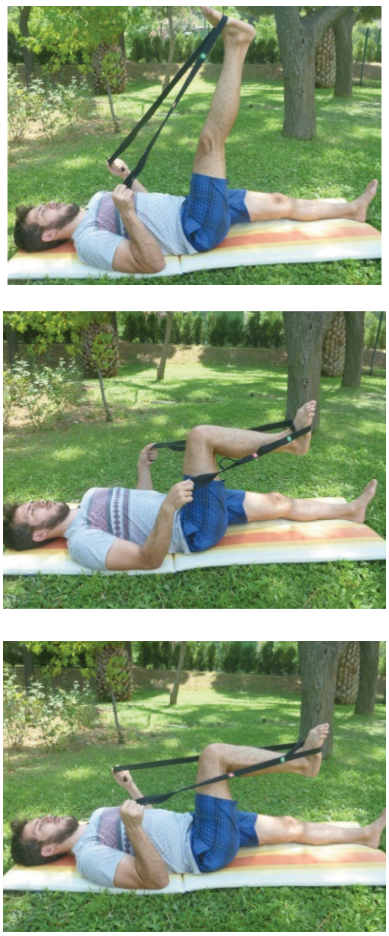
5-8. WEEK LAND EXERCISE PROGRAMME FOLLOWING EXERCISES WERE ADDED TO PREVIOUS PROGRAMME

19. Stretching out on one leg, take a deep breath and slowly stand up as exhale, repeat with the other leg (8 times for each leg)

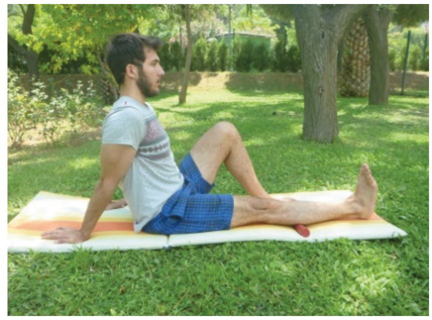
20. All-fours (quadruped) position on the floor mat, with your hands under your shoulders hands fingers facing forward. Walking forward with straight knees, feel the tense, breath, continue walking with arms. (8 repetition)

21. Place one foot and lower shin on the exercise ball. Flex the standing knee as pushing the ball backward stay for 15 sec repeat 3 times for each leg

22. Place one foot on the exercise ball, hold the wall for balance. Circle the ball for 8 times both clockwise and counter clockwise. Repeat for the other leg.



23. Supine lying TheraBand Stretch Strap placed on metatarsals stretch the strap with arms while knee flexed. Extend the knee against the stretched strap, maintain stretch for 15 sec. Repeat 3 times for each sides



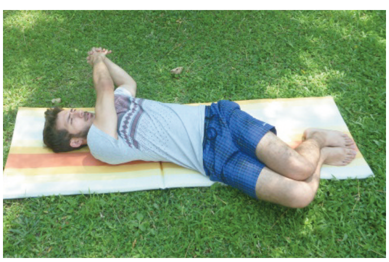
24. Place TheraBand Flexbar under right calf, bend left knee. Support with the hands move back and forth 8 times. Repeat with the other side

25. Place TheraBand Flexbar under right gluteus medius, place left foot in front of right knee. Support with the right elbow move back and forth in coronal plane 8 times. Repeat with the other side.

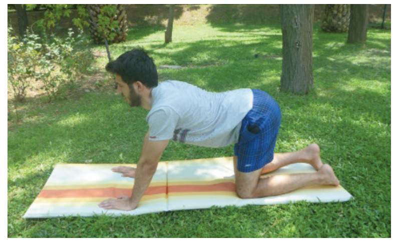
APPENDIX III

REPEAT EACH OF THE FOLLOWING EXERCISES AT LEAST 5 TIMES

Starting position: Lying on your back, both knees bent, feet on floor. Lift your hips off the floor as high as possible, hold for 5 seconds and lower slowly.



Lift your arms up in front towards the ceiling, with fingers linked. Take your arms to the right as far as possible while taking your knees to the left as far as possible. Turn your head to the same side as your arms. Repeat to the opposite side.



Starting position: Kneel on all fours. Keep your hands shoulder width apart and directly under your shoulders. Keep your knees hip width apart and directly under your hips. Keeping your elbows straight throughout, tuck your head between your arms and arch your back as high as possible. Lift your head and hollow your back as much as possible

Take your arms to the right as far as possible while taking your knees to the left as far as possible. Turn your head to the same side as your arms. Repeat to the opposite side.

CHAIR EXERCISES IN SITTING STARTING POSITION: SIT ON A STABLE KITCHEN/DINING ROOM CHAIR WITH YOUR FEET ON THE FLOOR, HOOKED AROUND THE LEGS OF THE CHAIR:

Place your hands by your sides. Hold the back of the chair with your left hand. Bend sideways as far as possible, without bending forwards, reaching your right hand towards the floor. Repeat to the opposite side

With your hands clasped on your forearms at shoulder level, turn your upper body to the right as far as possible. Repeat to the opposite side.

Hold the sides of the chair seat. Turn your head to the right as far as possible without letting your shoulders turn. Repeat to the opposite side.

Stand facing a kitchen chair, with a padded seat for comfort. Place your right heel on the seat, keeping the knee straight, and reach forwards as far as possible with both hands towards your foot. Feel the stretch at the back of your right thigh. Hold for 6 seconds. Relax. Repeat twice, stretching a little further each time. Relax. Repeat with the opposite leg.

Face the side of the chair and hold the chair back with your right hand. Bend your right knee and place your right shin on the seat Place your left foot forward as far as possible. Now place both hands behind your back. Bend your left knee as much as possible, keeping your head up and your back straight. Feel the stretch at the front of your right hip. Hold for 6 seconds. Relax. Repeat twice, stretching a little further each time. Relax. Turn round to face the other side of the chair. Repeat with the opposite leg.