Effect of different exercise rehabilitation programs with body weight reduction on reducing the time of injured limb efficient restoration before and after low knee osteotomy surgery

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Introduction

Lower limb osteotomies are a significant area in orthopaedic surgery and research, interested largely by a cumulative occurrence and distribution of osteoarthritis and other medical problems (Gao *et al.,* 2019).

In a normally aligned knee, the center of pressure passes somewhat to the medial side during extension. During flexion, the center of pressure is more medial. Axial varus malalignment leads to an abnormal load distribution across the medial compartment, pathologically disturbing both tibiofemoral osteochondral units and the medial meniscus. A 4% to 6% rise in varus malalignment significantly raises loading (up to 20%) in the medial compartment, disturbing the articular cartilage, the subchondral bone and the medial meniscus (Ziegler *et al.* 2015).

A knee osteotomy is a surgical operation whereby a bone is cut to shorten, lengthen or change its alignment to increase the stability of the knee and reduce the effects of arthritis (Brouwer *et al.,* 2014).

Knee surgery gives acceptable results in patients with advanced degenerative variations in the knee. The most public indications for this surgical process are osteoarthritis, rheumatoid arthritis and knee stiffness (Nawghare and Brooks 2013).

Satisfaction after knee surgery ranges between 75 and 90%. From a surgical point of view, joint line elevation is had a negative effect on surgical outcome, since it changes the biomechanics of the knee. By altering the center of rotation of the knee, the isometric of the medial collateral ligament is altered, with mid-flexion instability as a result. Moreover, as a result of the elevated joint line, the posterior condylar offset is likely to be condensed, which negatively influences flexion angle and the extensor mechanism strength, and resolves in mid-flexion instability (Lieshout *et al.,* 2018).

The pain that associated with knee surgery is often activity related (Syed and Wani 2014; Eitner *et al.,* 2017). However, pain is not the only consequence of knee surgery experienced by patients. Pain is related to

function, with physical movements triggering pain, while pain, in turn, causes restrictions in physical function (Castrogiovanni and Musumeci 2017).

The haematoma in the gap resulted from surgery is replaced by connective tissue in period ranges from four to six weeks (Fernandes *et al.,* 2011), which provides further callus formation and ossification, visible by three months after surgery (Brinkman *et al.,* 2008).

Postoperative therapy is done to reduce swelling. Starting on the first postoperative day, partial weight-bearing from 15 kg to 20 kg of the body weight is permitted. From four to six weeks the amount of weight-bearing allowed is based on the amount of pain, although after six weeks full weight-bearing is permitted. A full range of active and passive movement is encouraged, and started with the help of a physiotherapist (Brinkman *et al.,* 2008).

Many people with knee surgery are capable of performing independent land based exercise programs with an objective of maintain the health, improving knee function, and decreasing the risk of inactivity that associated with muscle disorder (Sisto and Malanga 2006). There is some evidence signifying that mechanical unweighting exercise may be more effective than weight bearing exercise in patients with medial knee problems (Bennell *et al.,* 2019).

Water based exercise may be an excellent alternative to land based exercise for individuals who have joint pain. It reduces the weight that joints, bones and muscles have to bear. Pressure of water consider as good reducing factor for swelling and load on painful joints while it is enhancing muscle relaxation. Aquatherapy causes many effects on the musculoskeletal system. The effects are caused by the compressive effects of immersion as well as reflex regulation of blood vessel tone. During immersion, it is expected that most of the improved cardiac output is redistributed to skin and muscle (Mooventhan and Nivethitha 2014). Some studies documented that patients must wait until two weeks after surgery to allow for wounds to heal and this may be slightly varied according to quality of individuals healing (Villalta and Peiris 2013). Depending on this rationale, the knee rehabilitation time may be delaying.

The rehabilitation with water based and land base exercises decreased level of pain, improved leg strength, flexibility and balance of the affected knee (Adnan *et al.,* 2014).

The present study aimed at assessing the effect of different exercise rehabilitation programs with body reducing weight on reducing the time of injured limb efficient restoration before and after low knee osteotomy surgery.

2. Materials and methods

2.1. Study sample

The study sample comprised twenty four patients (46-62 years–old) diagnosed with need for injured limb efficient restoration after low knee osteotomy surgery, had no issues of blood pressure, pulse, and breathing, they also had no consciousness or sensory disorders.

2.2. Study domains

2.2.1. Study time

Period: From February 2017 to May 2019.

2.2.2. Study place

Study was performed at health and sport scientific center Port Said.

2.2.3. Study approach

Study was performed using the experimental approach.

2.3. Experimental setup and working

The study sample was divided randomly to three experimental groups (each group composed of eight individuals), skew test was performed between different experimental groups before the knee surgery and treating programs for symmetry, it was between ±3.

The performed therapeutic exercise was based on recognized of impairments related to the knee osteoarthritis before and after the surgery, intensive mainly on strengthening, functional balance and muscle control.

Preoperative exercise was divided to two types: The first type was performed generally with all study groups focused on lower limb strengthening, with attention for strengthening of the quadriceps muscles. Before performing the main strength training program, subjects performed 20 minutes of ergometer bike. After the warm-up, patient applies a series of lower-body strengthening exercises, short arc extension, wall squat, leg press, isometric leg extension, and leg curls as well as other exercises according to the patient tolerance as showed in (Table 2.1), all study participates were received 4-week preoperative program (Kim *et al.,* 2015). The patient received 6 sessions /week.

While the second type was designed specifically for each experimental group as following: The first experimental group specific treating program was done using the mechanical unweighting, while the second experimental group treating program was done using the aquatherapy, and the last experimental group was applied the two previous treating program starting with mechanical unweighting program followed using the aquatherapy program.

Postoperative exercises use the traditional program for all groups were done immediately after surgery plus the suggested programs for each experimental group separately with different starting time.

Table 2.1: Preoperative exercise traditional program that all groups were done.

Exercises category	Exercises	Repetitions and set
Cardio exercise	Ergometer bike	(15-25) min
Range of motion exercise	Seat flexion/extension then wall slides	(8-12) min
Open-chain strengthening	Short arc extension	10×2 - 12×3
	Straight leg raises	10×2 - 12×3
	Leg curl (isometric)	10×2 - 12×3
Close-chain strengthening	Leg extension (ROM 30–80°)	10×2 - 12×3
	Leg press	10×2 - 15×3
	Half squat	10×2 - 15×3
Balance/Proprioception	Single-leg standing	30 sec×3 - 30 sec×5
	Balance board	30 sec×3 - 30 sec×5

2.3.1. Mechanical unweighting program

Done for four weeks before the surgery, then returned from the fourth week and ended at the twenty week after the surgery.

The patient received 5sessions/week, at least 30 minutes of moderate physical activity (Adams *et al.,* 2013).

Mechanical unloading during exercise was made by the use of a Zuni exercise system. This system used a harness suspended from a cable equipped with a tensiometer that permitted a preset weight reduction to be maintained during unweighting exercises and enabled subjects to perform exercises at 0%, 20%, and 40% of body weight support (BWS) (Mangione *et al.,* 1996). The exercises are summarized in Table 2.2.

Table 2.2: Mechanical un-weighting program from standing position that the first experimental group was done.

Exercises	Repetitions and set
Alternating knee raises	10× 2-3
Alternating leg raises	10×2-3

Alternating raised leg swings	20×2-3
Side leg raises	20×2-3
Rotate leg raises	10-20×2-3
Single leg circle	20×2-3
Raised knee extension	2-3×15
Knee stabilization	2-3×15
Heel and toe raises	2-3×20
Standing hamstring stretch	15-30 sec× 2-3
Quadriceps stretch	15-30 sec×2-3
Wide single leg squats	10×2-3
Cross leg side title	10 sec×2-3
Altering split squats	10×2-3
Each leg hamstring stretch	15 sec×2-3
Set-up	10-15×2-3
Butt kicks	10-15×2-3

2.3.2. The aquatherapy program

Done for four weeks before the low knee osteotomy surgery, then returned from the sixth week and ended at the twenty two week after surgery.

The program comprised functional weight-bearing and progressive exercises (Table 2.3) provided twice weekly (45–60 minutes each) (Hinman *et al.,* 2006; Sarsak 2018).

2.3.3. Combined effect of the two previous programs

Done for four weeks before the low knee osteotomy surgery, then returned from the fourth week and ended at the seventeenth week after surgery.

Table 2.3: Aquatherapy program that the second experimental group was done.

Phase	Exercises	Sets and repetitions	Walking
1	1. Double-leg squats 2. Double-leg calf raises 3. Dynamic lunge	2×10 2×10 2×10	6 min
2	As for phase 1	As for phase 1	8 min
3	As for phase 1, plus:	2×10 2×10	10 min

	4. Single-leg stance, contralateral knee flexion/extension 5. Single-leg stance, contralateral hip abduction/adduction 6. Single-leg stance, contralateral hip hitching	2×10	
4	1. Single-leg squats 2. Sincle-leg calf raises 3. Dynamic lunge Plus exercises 4, 5, and 6 from phase 3	2×10 2×10 2×10	10 min
5	As for phase 4, plus: 7. Step-ups	2×10	10 min
6	As for phase 5, but modify: 7. Step-downs	2×10	10 min
7	As for phase 6, but for exercises 4 and 5, increase speed (resistance) of moving leg as able	2×10 followed by 1×15	10 min
8	As for phase 7	3×10	10 min
9	As for phase 7	3×10 followed by 1×15	10 min
10	As for phase 7	4×10	10 min
11	As for phase 7	4×10 followed by 1×15	10 min
12	As for phase 7	5×10	10 min

All single-leg exercises were performed with both the left and the right legs. The step height was 145 mm.

Postoperative exercises were started immediately after surgery as showed in (Table 2.4); the patients were walking with the assistance of a pair of crutches without touching the ground, after two weeks, walking with the heels contacting the ground was allowed; with the fourth week partial weight-bearing was allowed as tolerated by the patient. After six weeks, full-weight bearing on a crutch. The patients walked without support after three months (Sarman *et al.,* 2019). The patient received 6 sessions /week.

Table 2.4: Postoperative exercise program that all groups were done.

Knee parameters / Exercises	0-2 weeks	3-6 weeks	7-12 weeks	13-17/22 weeks
ROM and flexibility				
Heel slides (+/-slider board, up wall)	◉	◉		
Seated active assisted knee flexion	◉	◉		
Seated calf and hamstring stretches	◉	◉		
Passive extension with roll under heel		◉		
Prone hangs (leg off bed)		◉		
Prone assisted knee flexion (belt, opposite leg)		◉		
Stationary bike (high seat ½ circles forward/backward → full circles → lower seat as tolerate		◉	◉	
Joint mobilizations (patellar, tib-femoral)			◉	
Quad stretches			◉	
Standing weight-bearing calf stretches: gastroc, soleus			◉	
Muscle strength and endurance quadriceps				
Isometric quads	◉	◉		
Quad over roll		◉		
Closed chain terminal extension with tubing: forward and backward facing		◉	◉	
Squats: wall, mini, 60°-90° (+/-wall)			◉	◉
Shuttle: leg press & calf press - 2 legs, 1leg (progress with ↑ resistance/reps)			◉	◉
Sit to stand: high seat, low seat, 2 legs, single leg			◉	◉
Leg press machine: 2-1 leg			◉	◉

Bungee cord walking: forward, backward, side step, lunging			◉	◉
Static Lunge: ¼-½-full, dynamic			◉	◉
Step ups (concentric):5-10-15-20 cm			◉	◉
Step down (eccentric): 5-10-15-20 cm			◉	◉
Hamstrings / Gluteals:				
Gluteal squeezes (supine or standing)	◉	◉		
Standing hip flexion/extension, abduction/adduction	◉	◉	◉	
Supine straight leg raise x four directions		◉		
S/L: clam shells		◉		
Prone knee flexion		◉		
Quadruped fire hydrant		◉		
Supine bridging: double, single, ball, +knee flexion		◉	◉	◉

Knee parameters / Exercises	**0-2 weeks**	**3-6 weeks**	**7-12 weeks**	**13-17/22 weeks**
Hamstring curls: prone, sitting, standing			◉	◉
Chair walking/stool pulls			◉	◉
Hip strengthening: weights, pulleys, tubing			◉	◉
Tubing kickbacks (mule kicks)			◉	◉
Shuttle standing kickbacks (hip/knee extension)				◉
Calves				
Ankle pumping +/- leg elevation	◉			
Plantar flexion with theraband		◉		
Calf raises: 2-1 foot			◉	◉
Up on toes walking			◉	◉
Eccentrics calves – heels drops 2-1 leg				◉
Proprioception				

Weight shifting (weigh scales)			◉	
Wobble boards, ½ foam roller, double, single leg			◉	◉
Squats, lunges on dynadisc, airex, bosu…			◉	◉
Single leg balance, time, complexity of skill			◉	◉
Standing 747s: eyes open, eyes closed, on mini tramp			◉	
Balance training with upper body patterning for sport			◉	
Cardiovascular fitness				
Bike		◉	◉	◉
Elliptical trainer			◉	◉
Treadmill: forward, backward, jog, run				◉
Sport specific training drills				◉

2.3.4. Tools:

In order to achieve the aim of the study, the following measuring parameters were performed: Height (m) using restameter, body weight (kg) using medical scale, the body mass index (BMI) (kg/m^2) (Misra and Dhurandhar 2019), (right and left) leg length (cm) using measuring tape, knee movement range (°) using the goniometer (Hancock *et al.,* 2018), Y balance test (YBT), that is applicable to provide an accurate assessment of the lower limb neuromuscular control. The individual should apply six times on each lower limb in each of the three directions before the main test. Must wear athletic shoes during the test and support foot positioned in the center of the Y balance test platform, leaning against the starting point. The maximum reach distance is measured by the measuring tape, at the point where the foot has reached (Neves *et al.,* 2017).

3. Results and discussion

No study participant left the research project for any reason. No side effects or complications were observed during the treatment.

Data collected using different measuring tools, revealed that there were equally maximum improvements in knee measurements in injured leg compared to healthy leg for the three experimental groups with different three exercise rehabilitation programs. The third experimental groups were reached to maximum improvements in 4+17 weeks followed by first group

4+20 weeks ended with second group 4+22 weeks. Results were presented in **Tables 3.4-3.9** and **Figures 3.1**and **3.2.**

To the best of our knowledge, this investigation is the first to examine the use of mechanical unloading or “un-weighting” technology and aquatherapy to support the reducing time of injured limb efficient restoration before and after low knee osteotomy surgery. Our results suggest that this combined method can be safely and successfully used to promote the speed of restoration before and after surgery without exacerbation of joint symptoms, and resulted in a significant decrease in knee joint pain, improved knee joint function, as well as a substantial increase in thigh muscle strength about the affected knee.

The patients who plan to undergo knee osteotomy surgery, preoperative rehabilitation program should be performed to enhance postsurgical outcomes. Rehabilitation should start as soon as possible after diagnosis (Filbay and Grindem 2019). Preoperative rehabilitation should be included knee extension range-of-motion and quadriceps strength should be specifically targeted as these factors are associated with poor post-surgical outcomes (Melick *et al.,* 2016).

The study results is in line with Peeler *et al.* (2015) who reported that, mechanical unloading or “un-weighting” is a safe mode of exercise that can be successfully used to decrease knee joint pain, improve joint function, and rise knee muscle strength. This result recommends that the reciprocal nature of muscle contraction observed during the low-load exercises helped a healthy balance in agonist/ antagonist strength about the knee and may improve functional capacity during the daily living activities.

A mechanical unloading or “un-weighting” can be a useful method in the rapidly transition from early postoperative phases up to the high phase of rehabilitation. The benefits of unloading are allowing early initiation of weight bearing and closed kinetic chain activities in a safe environment for healing tissue. Increased vertical ground reaction force and vertical loading have been linked with increased risk for stress injury or overuse injury. Declining these loads will allow safe acceleration of functional activity (Draovitch *et al.,* 2012).

Aquatic therapy results are in line with Kutzner *et al.* (2017); who reported that the aquatic therapy are frequently recommended for rehabilitation in order to enable mobilization and improve the muscle strengthening while minimizing the joint loads of the lower limb.

According to Michaels and Stevens (2019) study results, the cardiovascular function can also be enhanced as a result of aquatic therapy. Also declining the impact on sore joints will always be beneficial, allowing

individuals with knee deficient to exercise longer, building endurance, and eventually enhancing strength. This exercise in the water, when done with time, should eventually help the patients to move, not only better through the water, but also more efficiently through the air.

Rahmann (2010) study results, reported that when people with knee deficient find exercising in water an enjoyable and less painful activity, the compliance may be enhanced. The pool environment, with numbers of people exercising together, can be a positive environment and may have an effect on compliance and adherence to exercise for people with knee deficient, over and above the exercise program itself.

Wound healing is a complex process that needs understanding of different factors influencing it to improve healing times of wounds (Khalil *et al.,* 2015).

patients must wait until two weeks after surgery to allow for wounds to heal and this may be slightly varied according to quality of individuals healing (Villalta and Peiris 2013). Depending on this rationale, the knee aquatic therapy rehabilitation time may be delaying than the other study rehabilitation programs.

Table 3.4. Mean, ± SD and difference% between different experimental groups for demographic characteristics before and after the knee surgery and treating programs.

Variables	Group 1			Group 2			Group 3			Skew
	Before	After	Difference %	Before	After	Difference %	Before	After	Difference %	
Age	52.38 ± 4.31	52.38 ± 4.31	0.00	53.00 ± 4.54	53.00 ± 4.54	0.00	51.75 ± 5.65	51.75 ± 5.65	0.00	0.45
Height (m)	1.74 ± 0.06	1.76 ± 0.06	1.15	1.76 ± 0.05	1.78 ± 0.05	1.14	1.75 ± 0.06	1.77 ± 0.06	1.14	0.15
	85.00	81.00	- 4.71	83.38	80.06	-3.98	86.63	83.00	- 4.19	

Weight (kg)	± 7.95	± 7.27		± 9.49	± 8.95		± 6.16	± 7.15		-0.56
Body-mass index (kg/m²)	27.97 ± 1.82	26.03 ± 1.88	- 6.94	26.97 ± 2.75	25.32 ± 2.46	-6.12	28.22 ± 1.71	26.50 ± 2.19	- 6.09	0.01
Healthy leg length (cm)	93.00 ± 3.85	93.00 ± 3.85	0.00	93.75 ± 3.22	93.75 ± 3.22	0.00	93.50 ± 4.35	93.50 ± 4.35	0.00	0.13
Injured leg length (cm)	88.69 ± 3.69	92.06 ± 3.94	3.80	89.31 ± 3.10	92.81 ± 3.31	3.92	89.31 ± 4.68	92.38 ± 4.50	3.44	0.11

Group 1: Mechanical unweighting program

Group 2: Aquatherapy program

Group 3: Combined program

Skew: between different experimental groups before the knee surgery and treating programs for symmetry

Table 3.5. Mean, ±SD, difference between measuring time and difference (%) between injured and healthy knee flexion of different experimental groups with different measuring time and difference and difference (%) between legs.

Suggested program	**Measuring time**	**Injured knee flexion**				**Healthy knee flexion**				**Difference between legs**	**Difference (%)**
		Mean	**±SD**	**Difference between measuring time**	**Difference (%)**	**Mean**	**±SD**	**Difference between measuring time**	**Difference (%)**		
Group 1	**Measure 1**	102.63	6.14	-28.94	-28.20	46.88	3.36	-10.82	-23.08	55.75	-54.32
	Measure2	73.69	3.40	-22.44	-30.45	36.06	2.62	-4.18	-11.59	37.63	-51.07
	Measure 3	51.25	2.88	-19.69	-38.42	31.88	2.74	-3.07	-9.63	19.37	-37.80

	Measure 4	31.56	1.84			28.81	0.75			2.75	-8.71
Group 2	**Measure 1**	103.25	5.09	-27.37	-26.51	45.88	4.26	-7.07	-15.41	57.37	-55.56
	Measure2	75.88	6.73	-24.44	-32.21	38.81	3.05	-7.75	-19.97	37.07	-48.85
	Measure 3	51.44	5.21	-21.56	-41.91	31.06	2.19	-2.25	-7.24	20.38	-39.62
	Measure 4	29.88	1.90			28.81	1.31			1.07	-3.58
Group 3	**Measure 1**	102.50	6.05	-28.19	-27.50	46.50	4.11	-8.25	-17.74	56	-54.63
	Measure2	74.31	4.82	-23.25	-31.29	38.25	1.73	-7.39	-19.32	36.06	-48.53
	Measure 3	51.06	4.85	-21.31	-41.74	30.86	1.64	-1.92	-6.22	20.2	-39.56
	Measure 4	29.75	1.20			28.94	1.15			0.81	-2.72

Measure 1: Before surgery before the preoperative program (after diagnosis immediately)
Measure 2: Before surgery after the preoperative program (after 4 weeks)
Measure 3: After surgery before the postoperative program
Measure 4: After surgery after the postoperative program (after 2 weeks)

Table 3.6. Mean, ±SD, difference between measuring time and difference (%) between injured and healthy knee extension of different experimental groups with different measuring time and difference and difference (%) between legs.

Suggested program	**Measuring time**	**Injured knee extension**				**Injured knee extension**				**Difference between legs**	**Difference (%)**
		Mean	**± SD**	**Difference between measures**	**Difference (%)**	**Mean**	**± SD**	**Difference between measures**	**Difference (%)**		
Group 1	**Measure 1**	157.63	4.24	10.81	6.86	179.00	0.80	0.38	0.21	-21.37	-13.56
	Measure2	168.44	2.35	8.12	4.82	179.38	0.64	0.37	0.21	-10.94	-6.49
	Measure 3	176.56	2.61	3.13	1.77	179.75	0.38	0.13	0.07	-3.19	-1.81
	Measure 4	179.69	0.46			179.88	0.23			-0.19	-0.11
Group 2	**Measure 1**	158.63	5.34	11.75	7.41	179.44	0.82	0.25	0.14	-20.81	-13.12
	Measure2	170.38	4.78	4.93	2.89	179.69	0.46	0.12	0.07	-9.31	-5.46
	Measure 3	175.31	3.41	3.32	1.89	179.81	0.37	0.13	0.07	-4.5	-2.57
	Measure 4	178.63	1.33			179.94	0.18			-1.31	-0.73
Group 3	**Measure 1**	158.25	5.28	12.19	7.70	178.19	1.10	1.00	0.56	-19.94	-12.60
	Measure2	170.44	2.67	6.81	4.00	179.19	0.84	0.25	0.14	-8.75	-5.13
	Measure 3	177.25	2.96	1.81	1.02	179.44	0.73	0.25	0.14	-2.19	-1.24

	Measure 4	179.06	0.73			179.69	0.46			-0.63	-0.35

Measure 1: Before surgery before the preoperative program (after diagnosis immediately)
Measure 2: Before surgery after the preoperative program (after 4 weeks)
Measure 3: After surgery before the postoperative program
Measure 4: After surgery after the postoperative program (group 1 after 9 weeks, group 2 after 10 weeks and group 3 after 7 weeks)

Table 3.7. Mean, ±SD, difference and difference (%) between IKLF and HKLF for first group in y balance test three movements with time, difference (%) between time and IKLF and HKLF composite and the difference (%) between composite of IKLF and HKLF.

Measuring time	IKLF Anterior	HKLF Anterior	IKLF Posteromedial	HKLF Posteromedial	IKLF Posterolateral	HKLF Posterolateral	IKLF Composite	HKLF Composite	difference (%) between different measuring time of IKLF composite	difference (%) between different measuring time of HKLF composite	difference (%) between composite of injured and healthy knee leg fulcrum
Measure 1	22.81	46.56	35.38	61.69	29.38	62.63	29.19	56.96	16.20	7.76	-95.14
	±2.98	±4.13	±2.86	±4.03	±2.57	±4.62	±2.72	±4.14			
Measure 2	26.81	49.44	41.00	67.44	33.94	67.25	33.92	61.38	-11.79	3.80	-80.96
	±3.41	±4.25	±2.39	±3.81	±2.53	±4.90	±2.74	±4.29			
9 week	22.75	50.25	34.81	70.31	32.19	70.56	29.92	63.71	45.82	16.87	-112.93
	±2.71	±5.47	±1.94	±5.18	±2.22	±6.19	±2.23	±5.49			
10 week	32.56	55.19	49.13	84.06	49.19	84.13	43.63	74.46	17.03	6.94	-70.66
	±4.44	±7.05	±2.84	±4.44	±3.47	±6.85	±3.46	±5.94			
11 week	38.06	57.94	57.88	91.44	57.25	89.50	51.06	79.63	29.26	4.71	-55.95
	±5.01	±7.00	±3.45	±5.17	±4.22	±6.87	±4.16	±6.15			
12 week	49.25	61.44	75.00	95.38	73.75	93.31	66.00	83.38	9.56	0.47	-26.33
	±6.34	±7.14	±4.67	±4.99	±5.30	±6.75	±5.36	±6.14			
13 week	53.50	61.69	82.44	95.81	81.00	93.81	72.31	83.77	7.66	0.73	-15.85
	±6.42	±7.19	±5.04	±4.90	±5.81	±6.70	±5.63	±6.12			
14 week	57.63	62.19	88.75	96.38	87.19	94.56	77.85	84.38	5.36	0.81	-8.39
	±6.85	±7.28	±5.40	±4.71	±6.28	±6.82	±6.07	±6.10			
15 week	60.69	62.69	93.56	97.44	91.81	95.06	82.02	85.06	1.12	0.59	-3.71
	±7.14	±7.44	±5.55	±4.90	±6.76	±6.79	±6.35	±6.20			
16 week	61.50	63.13	94.56	98.13	92.75	95.44	82.94	85.56	2.13	0.42	-3.16
	±7.38	±7.55	±5.67	±5.32	±7.01	±6.85	±6.57	±6.39			
17 week	62.75	63.44	96.50	98.31	94.88	96.00	84.71	85.92	2.36	2.62	-1.43
	±7.61	±7.64	±5.76	±5.30	±7.17	±6.92	±6.74	±6.43			
18 week	64.38	65.63	98.94	100.81	96.81	98.06	86.71	88.17	0.55	1.24	-1.68
	±7.68	±7.02	±5.85	±4.83	±7.06	±6.55	±6.74	±5.95			
19 week	64.88	65.81	99.44	101.00	97.25	98.31	87.19	88.38	-0.22	0.00	-1.36

	±7.77	±7.07	±5.60	±4.82	±6.80	±6.44	±6.62	±5.95			
20 week	64.75	65.81	99.19	101.00	97.06	98.31	87.00	88.38			1.59
	±7.95	±7.07	±5.83	±4.82	±7.01	±6.44	±6.80	±5.95			

IKLF: Injured knee leg fulcrum, HKLF: Healthy knee leg fulcrum

Table 3.8. Mean, ±SD, difference and difference (%) between IKLF and HKLF for second group in y balance test three movements with time, difference (%) between time and IKLF and HKLF composite and the difference (%) between composite of IKLF and HKLF.

Measuring time	**IKLF Anterior**	**HKLF Anterior**	**IKLF Posteromedial**	**HKLF Posteromedial**	**IKLF Posterolateral**	**HKLF Posterolateral**	**IKLF Composite**	**HKLF Composite**	**difference (%) between different measuring time of IKLF composite**	**difference (%) between different measuring time of HKLF composite**	**difference (%) between composite of injured and healthy knee leg fulcrum**
Measure 1	21.63	44.31	35.25	58.88	27.63	60.44	28.17	54.54	15.44	14.98	-93.61
	±3.67	±3.95	±2.41	±3.61	±2.97	±4.35	±2.33	±3.54			
Measure 2	25.56	51.00	40.00	68.50	32.00	68.63	32.52	62.71	-8.06	4.54	-92.84
	±3.44	±4.02	±2.31	±3.67	±2.42	±4.54	±2.02	±3.70			
12 week	23.13	53.00	37.25	72.31	29.31	71.38	29.90	65.56	50.37	1.43	-119.26
	±3.43	±7.50	±2.42	±4.78	±2.90	±10.00	±2.34	±4.78			
13 week	33.00	53.69	51.88	73.69	50.00	72.13	44.96	66.50	19.68	3.82	-47.91
	±4.37	±7.20	±3.10	±5.11	±3.37	±10.18	±2.56	±4.83			
14 week	39.38	54.94	61.81	77.31	60.25	74.88	53.81	69.04	7.90	3.53	-28.30
	±5.22	±7.85	±3.46	±4.55	±3.85	±10.43	±2.91	±4.84			
15 week	43.06	54.94	66.44	80.13	64.69	79.38	58.06	71.48	10.92	3.18	-23.11
	±5.77	±8.70	±3.75	±4.22	±4.01	±10.63	±3.16	±4.62			
16 week	49.25	55.88	74.94	85.06	69.00	80.31	64.40	73.75	13.56	4.46	-14.52
	±6.62	±8.40	±4.31	±3.92	±4.08	±6.09	±3.42	±4.87			
17 week	55.44	56.75	85.31	89.63	78.63	84.75	73.13	77.04	9.82	4.69	-5.35
	±7.45	±8.37	±4.80	±3.71	±4.68	±5.75	±3.87	±4.68			
18 week	60.38	59.75	92.13	93.69	88.44	88.50	80.31	80.65	3.66	4.31	-0.42
	±8.13	±8.50	±5.53	±3.99	±5.17	±5.57	±4.26	±4.59			
19 week	62.25	63.19	95.13	97.25	92.38	91.94	83.25	84.13	2.33	2.62	-1.06
	±8.29	±8.77	±5.60	±4.41	±5.26	±5.43	±4.42	±4.48			
20 week	63.44	64.44	97.06	98.38	95.06	96.19	85.19	86.33	0.73	0.24	-1.34
	±8.49	±8.59	±5.48	±5.41	±5.10	±4.96	±4.28	±4.28			

21 week	64.13	64.75	97.75	98.56	95.56	96.31	85.81	86.54	0.20	0.00	-0.85
	±8.21	±8.30	±5.36	±5.23	±5.05	±5.11	±4.32	±4.19			
22 week	64.25	64.75	97.94	98.56	95.75	96.31	85.98	86.54			0.65
	±8.26	±8.30	±5.22	±5.23	±4.86	±5.11	±4.23	±4.19			

Table 3.9. Mean, ±SD, difference and difference (%) between IKLF and HKLF for third group in y balance test three movements with time, difference (%) between time and IKLF and HKLF composite and the difference (%) between composite of IKLF and HKLF.

Measuring time	**IKLF Anterior**	**HKLF Anterior**	**IKLF Posteromedial**	**HKLF Posteromedial**	**IKLF Posterolateral**	**HKLF Posterolateral**	**IKLF Composite**	**HKLF Composite**	**difference (%) between different measuring time of IKLF composite**	**difference (%) between different measuring time of HKLF composite**	**difference (%) between composite of injured and healthy knee leg fulcrum**
Measure 1	21.00	44.44	34.69	58.13	28.00	60.19	27.90	54.25	16.27	14.93	-94.44
	±2.82	±4.47	±2.42	±3.57	±2.84	±4.88	±2.56	±4.18			
Measure 2	25.13	51.25	39.13	68.38	33.06	67.44	32.44	62.35	-13.38	4.46	-92.20
	±3.29	±4.48	±2.53	±3.95	±2.60	±4.73	±2.75	±4.30			
9 week	22.00	53.06	35.19	73.25	27.13	69.06	28.10	65.13	27.83	2.69	-131.78
	±3.26	±7.40	±2.55	±5.07	±2.33	±4.07	±2.34	±5.19			
10 week	26.44	53.44	40.94	75.63	40.38	71.56	35.92	66.88	31.60	2.99	-86.19
	±3.31	±7.30	±1.97	±5.61	±3.17	±4.52	±2.71	±5.39			
11 week	35.25	54.25	53.81	77.81	52.75	74.56	47.27	68.88	22.91	6.40	-45.72
	±4.52	±7.49	±3.16	±5.81	±4.03	±4.89	±3.79	±5.70			
12 week	43.38	55.50	65.13	84.81	65.81	79.56	58.10	73.29	7.54	4.56	-26.14
	±5.71	±7.70	±3.60	±6.35	±4.98	±5.20	±4.67	±6.10			
13 week	46.69	57.50	71.25	88.81	69.50	83.56	62.48	76.63	14.00	7.11	-22.65
	±6.15	±8.50	±4.20	±6.64	±5.39	±5.80	±5.11	±6.76			
14 week	53.13	61.25	81.25	93.31	79.31	91.69	71.23	82.08	13.63	3.16	-15.23
	±7.06	±8.54	±4.68	±6.06	±6.05	±7.52	±5.76	±7.14			
15 week	60.38	63.00	92.13	96.13	90.31	94.88	80.94	84.67	5.53	2.11	-4.61
	±7.92	±8.27	±5.50	±5.60	±6.83	±7.41	±6.54	±6.85			
16 week	63.63	64.94	97.38	98.06	95.25	96.38	85.42	86.46	00.16	0.00	-1.22
	±8.37	±8.57	±5.46	±5.47	±7.29	±7.66	±6.82	±7.02			
17 week	63.88	64.94	97.44	98.06	95.38	96.38	85.56	86.46			1.05
	±8.45	±8.57	±5.40	±5.47	±7.38	±7.66	±6.85	±7.02			

The result of current study shows that use of mechanical unloading or "un-weighting" technology combined with aquatherapy can reducing the time of injured limb efficient restoration before and after low knee osteotomy surgery. This was agreed with Lund *et al.* (2008) study results, reported that the combination of aquatic and land-based exercise should be the preferred exercise regimen in knee rehabilitation. With addition that the land-based exercise must be done using mechanical unloading technology.

Aalderink *et al.* (2010) study documented that, the complete recovery after knee osteotomy surgery, defined as pain-free return to full activity, including unlimited exercise can take up to 24 weeks or longer after surgery. Our study results were demonstrated that, the third experimental group was reached to the improvement after 4 weeks preoperative rehabilitation program and 17 postoperative rehabilitation program.

Conclusion

There were equally maximum improvements in knee measurements in injured leg compared to healthy leg for the three experimental groups with different three exercise rehabilitation programs. The third experimental group was reached to maximum improvements after 4+17 weeks followed by first group 4+20 weeks ended with second group 4+22 weeks. Three experimental groups full flexion were performed at the end of the second week after surgery. Full extension for third, first and second experimental groups was performed at the end of the seven, nine and ten week after surgery respectively.

The combined effect of mechanical unweighting and aqua-therapy on reducing time of injured limb efficient restoration before and after knee osteotomy surgery was the most effective knee rehabilitation program in decreasing the rehabilitation time.

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