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Impact of Dynamic balance training on hip musculature moments and stability index in programming total hip arthroplasty

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Abstract:

Background: Aging impairs the central nervous system capability to process vestibular, visual and proprioceptive signals responsible for maintaining body balance. *Total hip replacement (THR) is a procedure, which can improve the quality of life in osteoarthritic patients. However, dynamic stability deficits and impairment in lower limb can be observed for several months after the procedure.* ***Purposes: to investigate the effect of dynamic balance training and traditional rehabilitation on hip musculature moments, and stability index in unilateral*** *total hip arthroplasty programming*. ***Methods: Twenty unilateral*** *total hip arthroplasty* ***patients aged from 55-75 years of both sexes, randomly divided into two groups, selected from Deraya University outpatient clinic. Group (A) (n=10) received traditional rehabilitation program only in form of therapeutic exercise, transfer training and gait training. Group (B) (n=10) received dynamic balance training program in addition to traditional rehabilitation programme. The subjects with unilateral THR were assessed at the beginning and at the 6th & 12th week post operatively after administering the rehabilitation programme in both groups using the following outcome measures: overall stability index, hip extension, abduction, and external rotation moments. Results: The results showed a significant improvement in dynamic balance in group (B) compared with those in group (A). There was no statistical significant difference between the group (A) and group (B) in the mean moments of hip extension, abduction, external rotation in mid stance at***

the initial, 6 weeks, and 12 weeks intervals except the external rotation at 6 weeks (p<0.05) Conclusion: Dynamic balance training is an effective method of programming unilateral total hip arthroplasty patients.

Keywords: Total hip arthroplasty, Dynamic balance, traditional rehabilitation programme.

Introduction

One of the main factors that currently limit the life of the geriatrics is imbalance. It originates between the ages of 65 and 75 years. (Shubert T E. 2011). Total hip replacement is one of the most successful and cost effective interventions in medicine. It offers a reliable relief of pain and considerable function improvement in patients suffering from hip osteoarthritis[1]. When conservative treatments fail to control the symptoms, joint replacement is performed. This procedure has high prevalence and associated costs, with the hips and knees being the joints operated upon most frequently. More than 1 million surgeries are performed every year in the United States (US) alone, with a total expenditure close to 13.7 billion and 28.5 billion US dollars for the hips and knees. The demand is expected to increase by approximately 700% by the year 2030 [2].

A substantial number may present with functional and balance limitations, even 1 year after joint replacement. These involve deficits in the proprioceptive system, with altered movement patterns and difficulties in walking and maintaining postural control, which consequently affect the performance of activities of daily living and quality of life [3].

Rehabilitation is essential and an integral part of the recovery process. The protocols are constructed to restore mobility and independence through muscle-strengthening and functional performance exercises. Balance and proprioception can be a key factor to achieve complete rehabilitation, especially if the positive association between balance abilities and functional capacities is considered [4].

The programs focused on restoring balance and proprioception have also been referred to as sensorimotor and neuromuscular trainings[5]. These improve the ability to generate a fast and optimal muscle-firing pattern. It is known that muscle imbalance can lead to movement impairments and yield a change in neuromuscular activation and motor control. By normalizing the peripheral proprioceptive structures and restoring the function of the nervous system, the dynamic joint stability is increased, and the ability to perform functional tasks can be relearned; this consequently improves muscle strength and postural control [6].

Materials and Methods

Subject:

Twenty subjects participated in this study, with age range 65-75 years, they were referred by the orthopedic surgeon with primary unilateral THA, they had complied with the inclusion criteria, were divided into two groups, one group participated in traditional rehabilitation program (group A) and the other group participated in dynamic balance training program in addition to traditional rehabilitation program (group B), The subjects with unilateral THA were assessed at the beginning and at the 6th & 12th week post operatively. **Group (A)**: This group consisted of ten patients had received traditional rehabilitation program for 12 weeks. **Group (B):** This group consisted of ten patients had received traditional rehabilitation program and dynamic balance training program for 12 weeks.

A quick physical examination and oral questionnaire were conducted with each subject prior to his/her acceptance into this study. The questionnaire was including demographic data, family history, past medical history (history trauma, disease & surgery), as well as present complaints. All subjects were inspected for postural asymmetry, and deformities. The examination consisted of checking for any muscle weakness, possible joint instability, leg discrepancy ≤ 1 inch, balance impairment, sensory abnormalities, vascular trouble, or other conditions that may affect the lower extremities and the spine. Patients were oriented to the procedures of training and assessment, informed for the requirements and assuring their understanding.

1-Balance testing

Biodex balance instrument: Biodex balance systems incorporated. Shirley, New York: Biodex Stability System (BSS) was used to measure balance at the Balance Lab, Faculty of Physical Therapy, Deraya University. The system provided measurement of OSI, MLSI and APSI. The reliability of the BSS has been reported. The device was calibrated before each measurement according to the manufacturer's manual [7]. Patients were instructed to step onto the platform of the BSS with the knee of the supported leg flexed about 10 degree. In addition the subject was instructed to keep his hands at his sides throughout the test. The platform was unlocked and the subject was instructed to adjust the foot position to a comfortable stable position. Then the platform was locked and the foot position coordinate was recorded. A single limb test was conducted. The test consisted of 30 s test using all eight levels provided by the system. The patient was asked to stand on the tested limb with the same foot coordinate that was determined at the pre-test and to look straight at the X mark and to try to maintain balance.

2- Gait assessment

The three-dimensional digital optical motion analysis system was used in the current study. This system can measure movement non-invasively with extreme accuracy in real-time. In this study, six cameras were set to record patients' movements[8]. It consisted of:

1- A "personal computer with Q Trac captures, Q Trac view, and Q gail soft wares installed.
2- Walkway (10m length), with one force plate form at its middle.
3- Camera system with 6 infrared cameras and ACB-530 serial interface adapter.
4- T shape wand and a reference structure for calibration of the system.
5- Passive marker system (15 diameters) to detect different body parts.

Treatment procedures:

Traditional rehabilitation programme[10]: Subjects in the group (A) trained in form of: Postoperative day 1: Bedside therapeutic exercises were initiated (ankle pumps, quadriceps sets, gluteal sets) for 5 to 10 repetitions time 1 to 3 each from supine position, then Bed mobility and transfer training (bed to/from chair) as tolerated. Postoperative day 2: Continued functional transfer training as sit to stand and bed to walker, then gait training was initiated with using walker for tolerated distance. Postoperative day 3-5: Continued therapeutic exercises in the form of active/ active assisted ROM and strengthening exercises within the subject's tolerance to reach 90° of flexion of hip and abduction 45° and progressive resistive exercises. Ambulation was continued on level surfaces and stairs with the least restrictive device (ambulation from few steps to at least 20 feet), the activity of daily living (ADL) training. Postoperative day 5 to 4 weeks: Stretching exercises to increase flexibility of hip muscles to flexion 90 degrees and abduction to 45 degrees, then Strengthening exercises, active assisted to active resistive e.g., seated leg extension, side lying/ standing hip abduction, standing hip extension and hip abduction, knee bends, bridging for 10 repetition time 3 each. Progression of ambulation was continued for at least 20 feet (7 meters) distance or as tolerated, then continued with ADL. **Balance training program:** Subjects in the dynamic balance group (group B) trained on balance board three times per week for 12 weeks, and assessed and reassessed on balance stability system. The training program required the subject to perform the training while standing in the same body position and the same stability level used during the testing.

Results

A total of 20 patients had participated in this study, they were assigned randomly in two groups; group (A) which consisted of 10 subjects with a mean age of 58.4 (± 4.48) years, and a mean sex (female/male) of (40/60%). The group (B) consisted of 10 subjects with a mean age of 61.9 (± 7.31) and a mean sex (female/male) of (30/70%). Using unpaired t-test showed that there were no significant differences between two studied groups for these demographic data (table.1).

Table 1. Demographic data in the two studied groups.

Variable	Group (A) (n= 10)	Group (B) (n= 10)	T test	
			t	p value
Age (yrs.)	58.4 ± 4.48	61.9 ± 7.31	-0.808	0.419
Sex (female/male)	40/60%	30/70%	-	0.639

There was a statistical improvement in the mean Biodex overall stability index in group (B) at 6 weeks and 12 weeks interval compared to the initial ($p< 0.01$) (table.2). There was a statistical significant difference in the mean Biodex overall stability index in the group (B) at 6 weeks, and 12 weeks ($p<0.01$). But there was no statistical significant difference in the group (A) across the intervals (table.3)

Table 2. Mean Biodex overall stability index at different time intervals of group (A), and (B).

Variable	Mean diff.	Std. deviation	Std. error	T test	
				t	P value
Overall stability index in group (B).					
Initial vs. 6 weeks	1.350	0.77064	0.24370	5.540	0.001**
Initial vs. 12 weeks	3.080	1.15258	0.36448	8.450	0.001**
Overall stability index in group (A)					
Initial vs 6 weeks	-1.001	1.91294	.60493	-1.655	0.132
Initial vs 12 weeks	-.320	1.33483	.42211	-0.758	0.468

Table 3. Biodex overall stability index in group (A), and (B).

Overall stability index in group (B).			
Initial	**6 weeks**	**T test**	
		t	**p value**
8.26 ± 1.83	6.91 ± 1.85	5.540	0.001**
Initial	**12 weeks**	**T test**	
		t	**p value**
8.26 ± 1.83	5.18 ± 1.79	8.450	0.001**
Overall stability index in group (A).			
Initial	**6 weeks**	**T test**	
		t	**p value**
8.37 ± 2.41	9.37 ± 1.52	-1.655	0.132
Initial	**12 weeks**	**T test**	
		t	**p value**
8.37 ± 2.41	8.69 ± 1.86	-0.758	0.468

** Significant at 0.01 level.

There was no statistical significant difference between the group (A) and group (B) in the mean moments of hip extension, abduction, external rotation in mid stance at the initial, 6 weeks, and 12 weeks intervals except the external rotation at 6 weeks ($p<0.05$) (table.4). There was no statistical significant difference in hip abduction moment in mid-stance at Initial vs. 6 weeks and Initial vs. 12 weeks in the Group (B). There was no statistical significant difference in moment of hip external rotation in mid-stance at Initial vs. 6 weeks and Initial vs. 12 weeks in the Group (B). There was no statistical significant difference in moment of hip extension in mid-stance at Initial vs. 6 weeks and Initial vs. 12 weeks in the Group (A). There was no statistical significant difference in mean moment of hip abduction in mid-stance at Initial vs. 6 weeks and Initial vs. 12 weeks in the Group (A). There was no statistical significant difference in mean moment of hip external rotation in mid-stance at Initial vs. 6 weeks and Initial vs. 12 weeks in the Group (A) (table.5).

Table 4. Mean moments of hip in mid stance in the two studied groups at initial, 6 weeks, 12 weeks intervals.

Variable		Group (A) (n= 10)	Group (B) (n= 10)	T test	
				t	p value
Hip extension	initial	1.11 ± 2.82	0.41 ± 0.75	-0.076	0.940
	6 weeks	0.945 ± 2.99	1.003 ± 2.513	-0.529	0.597
	12 weeks	-0.453 ± 1.628	0.022 ± 0.171	-0.455	0.649
Hip abduction	initial	0.31 ± 1.18	0.83 ± 1.16	-1.664	-.096
	6 weeks	0.363 ± 1.069	0.362 ± 0.759	-0.567	0.570
	12 weeks	0.326 ± 0.819	0.123 ± 0.246	-0.651	0.515
Hip external rotation	initial	-0.606 ± 2.195	-0.196 ± 0.385	-1.936	0.053
	6 weeks	-0.835 ± 2.722	-0.042 ± 0.059	-1.973	0.049*
	12 weeks	-0.272 ± 0.805	-0.091 ± 0.211	-0.305	0.761

** Significant > 0.05 level.

Table 5. Mean moment of hip extension, abduction, and external rotation in mid-stance at different time intervals in group (A), (B).

Variable	Mean diff.	Std. deviation	Std. error	T test	
				t	P vale
Mean moment of hip extension at different time intervals in group (B).					
Initial vs. 6 weeks	-0.596	2.68493	0.84905	-0.702	0.500
Initial vs. 12 weeks	0.385	0.68421	0.21637	1.779	0.109
Mean moment of hip abduction at different time intervals in group (B).					
Initial vs 6 weeks	0.464	1.02931	0.3255	1.426	0.188
Initial vs 12 weeks	0.703	1.24897	0.39496	1.78	0.109
Mean moment of hips external rotation at different time intervals in group (B).					
Initial vs. 6 weeks	-.154	0.40511	0.12811	-1.202	0.260
Initial vs. 12 weeks	-0.287	0.43858	0.13869	-2.069	0.068
Mean moment of hip extension at different time intervals in group (A).					
Initial vs 6 weeks	0.163	0.45382	0.14351	1.136	0.285
Initial vs 12 weeks	1.561	3.08461	0.97544	1.6	0.144
Mean moment of hip abduction at different time intervals in group (A).					
Initial vs 6 weeks	-0.054	0.185	0.0585	-0.923	0.380
Initial vs 12 weeks	-0.017	1.48846	0.47069	-0.036	0.972
Mean moment of hip external rotation at different time intervals in group (A).					
Initial vs 6 weeks	0.229	0.55129	0.17433	1.314	0.221
Initial vs 12 weeks	-0.878	2.26686	0.71684	-1.225	0.252

Discussion

Balance and proprioceptive deficits are frequently persistent after total joint replacement, improper functionality and produce movement patterns alterations and walking difficulties and maintaining postural control among THR patients. Clinically, balance trainings are a convenient complement to conventional physiotherapy care to produce an impact on balance and functionality[12].

Balance disorders in the geriatric population are often a multifactorial condition. Weakness in the core stabilizing muscles, altered muscle activation patterns, loss of proprioception, and an inability to control normal postural sway can all result in decreased balance in the elderly (Enix D E et al., 2011).

Balance and stability are important factors with aging, health complicated adults to maintain a healthy independent lifestyle. As people age, the ability to maintain balance becomes more difficult. Loss of balance is a primary factor in falls, which often results in serious injuries among the aged. Long periods of inactivity caused by fall injuries result in a decline in physiological capacity[19].

Shephard et al., 2000 found dynamic and static balance improved in all subjects that completed rehabilitation program vs. subjects that did not follow the program. Programs were: (Group1) strength training, (Group2) proprioception training, and (Group3) dynamic balance training[20].

Three basic mechanisms are invloved to obtain a sense of balance. The three mechanisms (visual, vestibular, and proprioceptive) interact to maintain posture and impart a conscious sense of orientation. Reflexes generally serve to maintain stability in posture (e.g. by extending muscle groups in the direction of an anticipated fall), or in maintaining stability of the visual field. A defect in one of these systems, or incongruous inputs amongst the systems can be compensated by reliance on the other two systems. However, such a defect decreases the subject’s overall ability to adjust to incongruous stimuli between the other two fields. Also, a defect can result in a serious subjective feeling of disequilibrium in the affected subject until compensation for the deficit occurs[20].

So conducting this study to find out the effect of balance training using wobble board three times per week for 12 weeks on the improvement of balance deficits, and moment of operated hip muscles in the three planes with total hip replacement subjects. With sharing of 20 male and female subjects who have been through THR, aged from 55 to 75 and were assigned randomly into two groups. Subjects in the group (A) (n=10) received traditional rehabilitation program in form of therapeutic exercise, bed mobility training, transfer training and gait training. While subjects in the group (B) (n=10) were treated by using traditional rehabilitation program as well as balance training program. Dynamic balance, and hip muscles moments in the three planes were assessed initially, then on 6 weeks and then on 12 weeks interval for both groups.

From statistical analysis of the three intervals (initial, 6weeks and 12weeks) of dynamic balance in the group (B), there was improvement determined by the Biodex stability system report in the 6 weeks and 12 weeks interval rather than the initial scores and this difference was significant. Improvement in balance may be due to traditional rehabilitation program and may be attributed to participation in strengthening exercises and functional mobility training, and balance exercises added to a typical rehabilitation program resulted in significantly greater improvements in balance and functional mobility compared to typical exercises alone[15]

To examine the effect of dynamic balance training program on the group (B) using balance stability system (Biodex) comparing the overall stability index of the initial assessment to the 6 weeks assessment score and then to 12 weeks assessment score, the result shown highly significant changes in the overall stability index, this result comes in agreement with **Woollacott M. H., 2002** Dynamic balance training is a beneficial training modality. When exercised in the balance training mechanical apparatus used in this study enables efficient balance and mobility training without requiring physical assistance from a physiotherapist or a caregiver, which opens new possibilities for continuing and more frequent physical exercise and mobility training[19].

All subjects in both groups have been operated with THA recently with the postoperative manifestations of functional impairments were investigated to examine the effect of traditional rehabilitation programme, and dynamic balance training program on hip musculature moments using motion analysis in the three planes ,the comparison between the moment of the hip muscles in the three directions has revealed that there was no significant difference of the moments from the initial assessment to the 6 weeks assessment and even further to the 12 weeks assessment , however there was no significant difference between the moments of group (B) to group (A) in the same interval of assessment in AP (extensor) moment neither in ML (abductor) while there was a significant difference in the transverse plane (external rotator) in the favor of the group (B).

Gotze C. et al., 2003 demonstrated that there is a reduction in hip abductor moment, Gait dysfunction is revealed in decreased hip extension and deficient hip abduction[13]. Also subjects after THA had shown balance deficits which agree with **Lugade et al., 2008**, who reported that impairment in the hip muscles and developed joint dysfunction result in increased risks of falling and causing balance problems[14].

The subject's muscle force in isometric nature for involved hip extension, hip abduction, and knee extension improved by 86%, 138%, and 33%, respectively; balance improved by 400%; balance confidence increased by 41%. Also the ability to perform lower-extremity functional activities increased by 20%[16].

Regarding changes of the moment of the hip joint musculature after replacement by using motion analysis by qualysis system, Q view, and Q gait software analysis, there was an improvement in the moment of hip extensors and abductors in both groups (A, B) which was insignificant while there was improvement in the moment of the external rotator in both groups however it was significant in group (B). It was reported that there were functional impairments after hip arthroplasty. The results demonstrated that, there is a reduction in hip abductor moment. There was a significant decrease in the hip extension at the end of the stance phase. Compensation of gait instability observed in an extended stance phase. The gait analysis confirmed objective impairments of the operated hip and neighboring joint. Gait instability is revealed in decreased hip extension and deficient hip abduction[21]. A recent systematic review of progressive resistive training in elderly people has shown a strong positive effect on leg extensor muscle force with moderate- to high-intensity training[18].

The findings have been supported by a previous study by **Crory et al., 2001** who found that, after hip arthroplasty, many subjects continue to exhibit abnormal gait patterns. The purpose of their study was to compare the vertical ground reaction forces of a group of 27 individuals with total hip replacement with a group of 35 normal control subjects by using two force plates in instrumented treadmill. Their results demonstrated that the stance time was significantly less, while time to first peak force was significantly greater on the affected leg of the hip arthroplasty subjects when compared to their unaffected leg, or to the group (A). The hip arthroplasty group showed greater asymmetry of GRFs than the group (A) did. Bilateral asymmetric limb loading persists after unilateral hip replacement surgery[17].

Conclusion

Bending on the presented data, it is possible to conclude that balance training program is effective with traditional rehabilitation program in improving dynamic balance with subjects who have been operated with unilateral primary THA recently. Also, no effect of balance training in increasing the moments of hip extension, abduction, external rotation in mid stance at the initial, 6 weeks, and 12 weeks intervals except the external rotation at 6 weeks postoperatively.

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