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The effect of structural changes of the lower limb on the restoration of the efficiency of the prosthetically replaced knee joint.

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Abstract:

The knee joint is one of the largest and most complex joints in the body, bearing the majority of the body's weight during daily activities. It consists of bones, cartilage, ligaments, and the articular capsule. Knee joint replacement is a major surgical procedure indicated for severe arthritis, persistent pain during weight-bearing or movement, extensive cartilage damage, significant joint deformity, instability, limited mobility, or failed non-surgical treatments. There are two types of knee replacements: total knee replacement and partial knee replacement.

Scientific importance:

The current study represents one of the scientific efforts aimed at examining the structural changes in rehabilitation programs following knee replacement surgery for patients who have undergone this procedure. The structural changes caused by unbalanced warm-ups on the various joints of the lower limb must be considered.

Applied importance:

The findings of the current study may highlight the importance of focusing on the rehabilitation of morphological variables and the Q-angle after knee joint replacement, given their impact on the success of the rehabilitation program.

Study domains:

Spatial Domain:

- *The study was conducted at the Endoscopy and Joint Change Clinic of Dr. Amir Ahmed Odeh in Alexandria.*

Temporal Domain:

- *Preliminary measurements were taken between December 13, 2023, and April 14, 2024.*
- *The main study was conducted from December 15, 2023, to July 15, 2024.*
- *Post-measurements were carried out between April 16, 2024, and July 17, 2024.*

Keywords: *(the Kinetic efficiency, Structural changes, Mechanical stress, Knee replacement)*

Introduction:

The knee joint is one of the largest and most complex joints in the body, bearing the majority of the body's weight during daily activities. It consists of bones, cartilage, ligaments, and an articular capsule.

Due to its position between two long bones, the femur (thigh bone) and the tibia (leg bone)—the knee joint is highly susceptible to traumatic injuries. Its stability relies primarily on surrounding ligaments and muscles rather than its structural formation. Damage to these tissues can be severe enough to necessitate surgical interventions, including knee joint replacement.

Knee joint problems range from cartilage degeneration (osteoarthritis) to ligament, cartilage, or muscle injuries. Common causes of knee pain include excessive weight-bearing with the knees fully bent, degeneration of joint components due to aging, improper use of the lower limbs, significant weight gain, pathological conditions, or weakness in the muscles supporting the knee.

When joint damage impairs mobility and balance, proper care and rehabilitation become essential. Additional causes of knee pain include improper joint use in daily activities, structural wear due to pathological conditions, mechanical changes in load distribution, or muscle weakness around the knee.

Tibial Tendon Insufficiency Syndrome

(This condition leads to acquired adult flatfoot.)

Knee joint replacement is a major surgical procedure indicated for severe arthritis, persistent pain during weight-bearing or movement, extensive cartilage damage, significant joint deformity, instability, limited mobility, or failed non-surgical treatments. There are two types of knee replacements: total knee replacement and partial knee replacement.

The Q-angle (quadriceps angle) varies depending on quadriceps contractions slightly decreasing when contracted. It increases with lateral leg rotation and can be measured via X-ray. Post-replacement, stress distribution on knee structures must be considered. Factors such as increased medial hip rotation, patellar misalignment, tibial medial rotation, and heel height can contribute to knee pain, as the lower limb functions as a closed kinetic chain, especially after joint replacement.

Bone Mechanics and Structural Adaptations:

The mechanical properties of axial bones are complex, influenced by composition, bone strength, rigidity, and energy absorption. These properties vary based on load direction, rate, and type. Bones must withstand multiple forces simultaneously, resisting gravity while supporting body weight.

Structural changes in the pelvic joint also significantly influence recovery rates after knee replacement.

Rehabilitation Considerations:

Drawing from clinical experience in rehabilitation and orthopedic settings, as well as previous research on post-surgical recovery programs, an effective rehabilitation plan should:

Address morphological factors affecting knee function and overall body mechanics.

Correct functional weaknesses caused by pre-surgical structural impairments to enhance joint stability.

Optimize functional performance in the replaced knee and improve overall joint functionality.

Research importance:

Scientific importance:

The current study represents one of the scientific efforts aimed at examining the structural changes in rehabilitation programs following knee replacement surgery for patients who have undergone this procedure. The structural changes caused by unbalanced warm-ups on the various joints of the lower limb must be considered when designing post-operative rehabilitation programs. Pre-surgical gait alterations at the knee, pelvis, and ankle levels have varying effects after knee replacement surgery. Although the surgical procedure targets only the knee joint, the pelvic and ankle joints are also impacted due to prior load imbalances resulting from the knee joint's condition. Therefore, it is essential to account for the functional characteristics of these joints and work to improve their mobility, which can be achieved by enhancing their range of motion.

Applied importance:

The findings of the current study may highlight the importance of focusing on the rehabilitation of morphological variables and the Q-angle after knee joint replacement, given their impact on the success of the rehabilitation program. Proper attention to these factors can help achieve balanced load distribution on the feet during movement, strengthen and support the muscles, and improve overall balance and stability—particularly in the knee joint, as well as in other joints of the body.

Research objectives:

The research aims to identify the impact of a rehabilitation program on certain structural variables related to joint improvement after knee replacement surgery. This will be achieved through the following tasks:

1. Design a rehabilitation program to improve structural variables post-knee replacement.
2. Enhance joint range of motion (ankle - knee - pelvis).
3. Reduce pain in the affected area.
4. Improve skin thickness and fat distribution metrics.

Research hypotheses:

1. Significant differences exist between pre- and post-measurements in structural variables.
2. Significant differences exist in the range of motion, favoring post-measurements.
3. Significant differences exist in pain levels, favoring post-measurements.
4. Significant differences exist in skin thickness and fat metrics, favoring post-measurements.

Keywords

- **Rehabilitation**

Rehabilitation involves restoring the full function of an injured individual. It primarily depends on identifying the causes of the injury, conducting a proper evaluation, and applying appropriate treatment methods. A successfully rehabilitated person can perform essential functions and daily activities, such as walking, climbing stairs, and meeting life's demands, without impairment. (80:34)

- **Structural changes**

Structural changes refer to alterations in a cell's form, including modifications in size, shape, structure, or function. (71)

- **Mechanical stress**

Mechanical stress is defined as the internal force divided by the cross-sectional area of the surface on which the force acts. (95:7)

- **Knee replacement**

Knee replacement is a surgical procedure in which the damaged surfaces of the thigh bone (femur), tibia, and patella are removed and replaced with artificial components. This eliminates pain caused by bone friction and improves the knee's range of motion. (1603:12)

Materials and methods

First: Research Methodology:

To achieve the research objectives and align with the nature of its variables, the researcher employed an experimental approach using a single-group design with pre- and post-measurements.

Study domains

Spatial Domain

– The study was conducted at the Endoscopy and Joint Change Clinic of Dr. Amir Ahmed Odeh in Alexandria.

Temporal Domain

– Preliminary measurements were taken between December 13, 2023, and April 14, 2024.

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– Post-measurements were carried out between April 16, 2024, and July 17, 2024.

Human Domain

- The research involved a sample of patients who underwent total knee replacement surgery at the Arthroscopic and Joint Replacement Clinic of Dr. Amir Ahmed Odeh.

Research sample

The research sample was intentionally selected from patients who underwent total knee replacement surgery, with a total of six (6) cases included.

- Conditions for selecting the sample

Third: Means and tools of data collection.

Research tools:

- **Arab and foreign references**

All references used were in the field of post-surgical joint replacement rehabilitation and proved beneficial to the researcher.

- **Testing and Measurement**
- **Personal interview**

The researcher employed the following methods for data collection:

- **Scientific references related to the study topic**
  - Previous research and studies, as well as information from international networks and the opinions of rehabilitation specialists, were used to design the rehabilitation program registration form for knee joint prostheses.
  - A dedicated data registration form was used to record pre- and post-measurements, including: (Age - Height - Weight - Thigh and leg circumference - Pain level - Range of motion in the knee joint after replacement - Electrical potential of the muscles - Y Balance - Q-angle - Flexibility measurement of the posterior thigh muscles).
- **Selection of assistants.**

Four (4) assistants were selected, including sports injury specialists, clinic nursing staff, and highly qualified photographers. They were briefed on the study's objectives, patient name registration procedures, tool preparation, and test measurements in the clinic. Additionally, they were trained in proper measurement techniques and accurate data recording in the collection form (see Attachment 5).

- General measurements (primary variables)

The researcher collected the following patient data:

- (Age -Height-Weight)

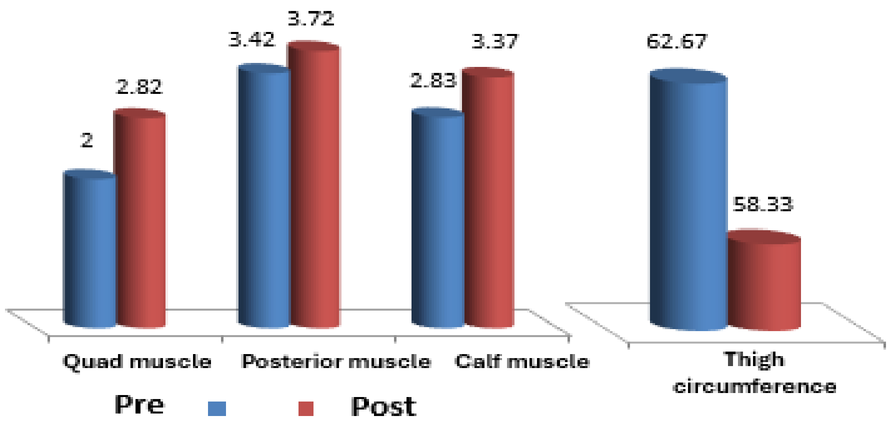
Table (1)

presents the statistical significance of measurements, including skin layer thickness, fat percentage, groin circumference, and improvement rates before and after the experiment for the research sample (n = 6)

Statistics / *Measurements*	*Pre-measurement*		*Post-measurement*		*Difference between the means*		*value*	*Significance level*	*% improvement*
	s	*a*	*s*	*a*	*S*	*±P*			
Quad muscle	***2.00***	***0.89***	***2,84***	***5.56***	***0.82***	***0.31***	***6.5***	***0.00***	***40.83%***
Posterior muscle	***3.42***	***1.34***	***3,72***	***6.40****	***0.30***	***0.20***	***3.27***	***0.01***	***8.78%***
Calf muscle	***2.83***	***1.16***	***3,37***	***3.67****	***0.53***	***0.47***	***2.79***	***0.04***	***18.82%***
Thigh circumference	***62.67***	***11.43***	***58.33***	***2.79****	***4.33***	***7.63***	***1,39***	***0.22***	***6.91%***

Table (1) and Figure (1) demonstrate the statistical significance of skin layer thickness, fat, groin circumference, and the percentage of improvement before and after the experiment. The results show statistically significant differences at the 0.05 level in the measurements of the quadriceps, posterior muscle, and calf muscle, with calculated (T) values ranging from 2.79 to 6.40. These values exceed the tabulated (T) value of 2.57 at the 0.05 significance level, and the p-values were less than 0.05. However, no statistically significant differences were observed in groin circumference measurements. The improvement rates in skin layer thickness, fat, and thigh circumference ranged from 6.91% to 40.83%, with post-measurement values showing greater improvement.

Figure (1)



displays the differences between the pre- and post-measurement averages for skin layer thickness, fat, and groin circumference before and after the experiment

Table (2)

presents the effect size significance, measured by ETA squared, for the skin layer thickness, fat, and groin circumference measurements (n = 6)

Statistical / *semantics*	*Unit of measurement*	*value (v)*	*Significance level*	*ETA2*	*Significance of impact size*
Quad muscle	***Cm***	***6,40***	***0.00***	***0.89***	***High***
Posterior muscle		***3.67***	***0.01***	***0.73***	***High***
Calf muscle		***2,76***	***0.04***	***0.61***	***High***
Thigh circumference		***1,39***	***0.22***	***0.28***	***low***

**** Effect size value: 0.00 to less 0.29 low 0.30 to less 0.50 medium 0.50 to 1 high.***

Table 2 shows the significance of the effect size for measurements of skin layer thickness, fat, and groin circumference based on the ETA square. The effect size values for the measurements (quadriceps, posterior muscle, and fat muscle) ranged between 0.61 and 0.89, which are above the threshold of 0.5, indicating a high effect size in these measurements. In contrast, the effect size for thigh circumference was low.

Figure (2)

displays the effect size values for the measurements of skin layer thickness, fat, and groin circumference after the experiment.

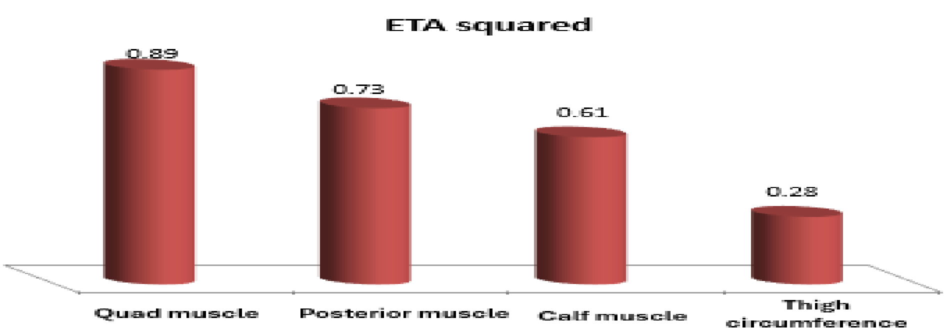


Table (3)
presents the statistical significance of the visual symmetry scale for pain and the percentage of improvement before and after the experiment in the research sample (n = 6)

Statistics / Measurements	Pre-measurement		Post-measurement		Difference between the means		value (v)	Significance level	% improvement
	x`	±P	x`	±P	x`	±P			
Visual symmetry of pain	9.25	0.76	1.92	0.86	7.33	0.75	23.86	0.00	79.23%

**** Tabular value (T) is significant at the level of 0.05 = (2.57)***

Table (3) and Figure (2) demonstrate the statistical significance of the visual symmetry of pain scale and the percentage of improvement before and after the experiment. The results show statistically significant differences at the level of (0.05), with a calculated (T) value of (23.86), which is greater than the tabular (T) value of (2.57) at the (0.05) level. The significance level was less than 0.05, and the improvement percentage in the visual symmetry of pain scale was (79.28%) in favor of the post-measurement.

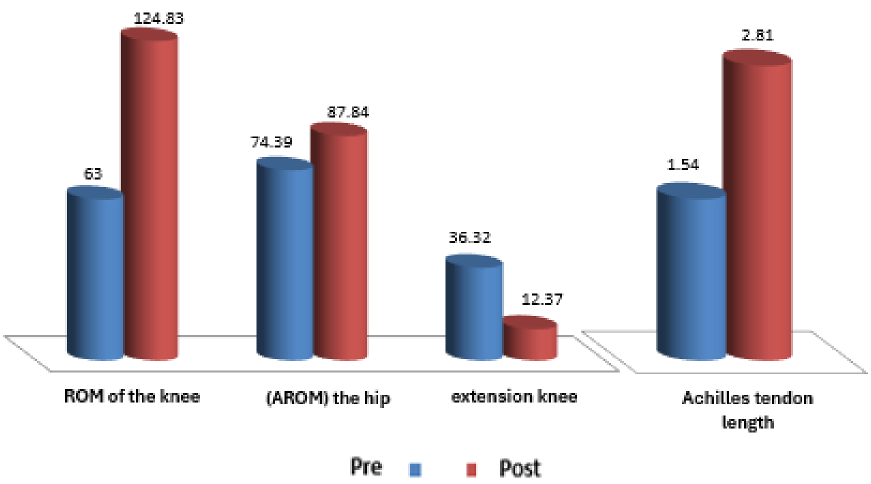
Table (4)
presents the statistical significance of the range of motion measurements and the percentage of improvement before and after the experiment for the research sample (n = 6)

Statistics / Measurements	Pre-measurement		pos-measurement		Difference between the means		value (v)	Significance level	% improvement
	x`	±P	x`	±P	x`	±P			
Range of motion (ROM) of the knee	63.00	4.20	124.83	8.18	61.83	6.49	23.32*	0.00	98.15 %
Active range of motion (AROM) the hip	74.39	10.61	87.84	8.47	13.45	3.26	10.11*	0.00	18.07%
Test extension (TE) knee	36.32	9.32	12.37	3.44	23.94	6.99	8.39*	0.00	65.93%
Achilles tendon length test for ankle	1.54	0.36	2.81	0.45	1.27	0.29	10.80*	0.00	82.47%

**** Tabular value (T) is significant at the level of 0.05 = (2.57)***

As shown in Table (4) and Figure (3), the statistical significance of the range of motion measurements and the percentage of improvement before and after the experiment is evident. There are statistically significant differences at the 0.05 level in all measurements, with calculated (T) values ranging from 8.39 to 23.32. These values exceed the tabular (T) value at the 0.05 significance level (2.57), and the significance levels are all below 0.05. Additionally, the improvement rates in the range of motion measurements ranged between 18.07% and 98.15%, favoring the post-experiment measurements.

Figure (3)
displays the effect size values for the measurements of skin layer thickness, fat, and groin circumference after the experiment



Discussion of results:
By reviewing reference studies and research in this field, as well as consulting specialists in injury rehabilitation, physical therapy, therapeutic exercises, and rehabilitation, it became evident that there is a lack of dedicated programs targeting the development of certain morphological variables in knee joint rehabilitation following total replacement surgery. These programs should account for variations in different body joints and incorporate modern rehabilitation methods.

Table (1) and Figures (34) and (35) demonstrate the statistical significance of measurements related to skin layer thickness, fat percentage, groin circumference, and improvement rates before and after the experiment. The results show statistically significant differences ($p < 0.05$) in the measurements of the quadriceps muscle, posterior muscle, and fat percentage, indicating the effectiveness of the applied rehabilitation program.

Additionally, the effect size (measured by ETA squared) was high (ranging from 0.61 to 0.89) for skin layer thickness, fat percentage, and muscle measurements—values exceeding the 0.5 threshold. However, the effect size for groin circumference was relatively low.

These findings highlight the success of the rehabilitation program, which incorporates targeted exercises designed to address morphological variables. This approach helps reduce skin layer thickness, fat accumulation in muscles, and postoperative fat infiltration.

The results align with previous studies by Rasha Fareed (2007) and Talal Daif, confirming that the proposed rehabilitation program improves certain physical measurements in the research sample.

The proposed rehabilitation program, given its focus on morphological variables, has a positive effect on improving outcomes—reducing joint swelling, skin thickness, and fat layer.

Table No. (2) and Figure No. (2) demonstrate the statistical significance of the visual symmetry pain scale and the improvement percentage before and after the experiment. Statistically significant differences were observed at the 0.05 level, with a calculated (T) value of 23.86—exceeding the tabular (T) value of 2.57 at the 0.05 significance level. The improvement rate in the visual symmetry pain scale was 79.28%, favoring post-measurement results.

This improvement can be attributed to enhanced joint range of motion through standardized rehabilitation methods and structured exercises. Stretching exercises improve flexibility, motor skills, tissue healing, and muscle pain relief. These findings align with the research of Osama Riad and Nahed Ahmed (2001), who emphasized the benefits of physical exercise.

Table No. (3) and Figure No. (4) further confirm the statistical significance of range-of-motion measurements and improvement percentages before and after the experiment. Significant differences were found at the 0.05 level across all measurements, with calculated (T) values ranging from 8.39 to 23.32—all exceeding the tabular (T) value of 2.57 at the 0.05 significance level. Improvement rates in range-of-motion measurements varied between 18.07% and 98.15%, favoring post-measurement results.

Additionally, the improvement percentage in the quadruple bite angle (Q angle) measurement was 59.62%, again favoring post-measurement outcomes.

Conclusion:
In light of the research objectives, methodology, sample scope, and statistical analysis—along with the presentation and discussion of the results—the researcher concluded that the proposed rehabilitation exercise program contributed to

restoring therapists who underwent surgical knee joint replacement to a semi-normal state. This conclusion is supported by the following findings:

1. Restoration of electrical activity in the muscles supporting the knee joint after total knee replacement surgery, as evidenced by comparative pre- and post-measurement results.
2. Recovery of the knee joint's range of motion within the anatomical kinetic limits of the artificial joint, along with improved motor function, as demonstrated by pre- and post-measurement results.
3. Reduction in pain levels among patients, as shown by pre- and post-measurement comparisons.
4. Restoration of motor flexibility, achieving the permissible anatomical range of motion for the artificial knee joint.
5. Improvement in skin thickness and fat composition around the joint.
6. Enhanced electrical activity in the affected muscles.
7. Effectiveness of the proposed training program in rehabilitating the artificial knee joint.
8. Importance of medical oversight to monitor physiological changes during rehabilitation.
9. Significance of patient education, including guidance on joint care and activities to avoid.
10. Focus on restoring the patient’s full functional performance.
11. Successful implementation of the studied rehabilitation program for artificial knee joint recovery.

Recommendations:

- Continue performing rehabilitation exercises after the program ends, particularly muscle-strengthening exercises and range-of-motion exercises for the knee joint, to restore full physical function.
- Consider pre-surgical rehabilitation before knee replacement surgery (References).

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