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Original paper

Torque of the shank rotating muscles in patients with knee joint injuries

MARIUSZ HRYCYNA[1]*, JACEK ZIELIŃSKI[2]

[1] The Halina Konopacka University of Physical Education and Tourism, Pruszków, Poland.
[2] The Józef Piłsudski University of Physical Education, Warsaw, Poland.

The aim of the study was to evaluate the torque of the shank rotating muscles in patients with reconstructed anterior cruciate ligament (ACL) and rehabilitation accomplished in comparison with a control group. The study was carried out on the group of 187 males. For the purpose of the study a prototype testing device for the shank rotating muscles' torque under static conditions was used. The study was based on the measurement of maximal torque at selected angles (–30°, 0°, 45°) of the shank rotation as well as on the angle (30°, 60°, 90°) of flexion of the knee joint. The results obtained in the group with reconstructed anterior cruciate ligament (ACL) and rehabilitation accomplished were comparable to those the control group and mostly of no statistical significance. Lack of significant differences between the values of shank rotating muscles' torque achieved in an injured limb compared to an uninjured one may testify to an effective rehabilitation process. The results of the research can serve as a diagnostic tool for the rehabilitation process development.

Key words: *torque, knee, rotation, anterior cruciate ligament*

1. Introduction

The measurements of torque and the range of movement in joints are important sources of information used in biomechanics, theory of sport, ergonomics, medicine as well as physiotherapy. In a contemporary rehabilitation, the assessment of its effectiveness is based on the improvement of general muscle strength in connection with a physical training. This training should provide the recovery of full range of muscle movement, strength, proprioception and not be focused only on the improvement of one muscle group. An evaluation of muscle strength and joint movement range is one of the basic diagnostic methods of assessing motor organs and progression of rehabilitation [13], [15]. The range of joint movement is measured by a goniometer which should provide sufficient outcomes. The tests used to measure the muscle strength (e.g., Lovett's test) are very subjective. This may create a need for new, more precise methods of measuring torque in various body planes and axes and better training methods [1], [16].

In the medical literature, the studies on passive motor system such as reconstruction and transplantation of ligaments are widely present. This knowledge is essential for proper surgical procedures and more advanced reconstruction of joints, possibly close to biomechanics of a healthy organ [3], [5].

The aim of the study was to evaluate the torque of the shank rotating muscles at selected angles of the shank rotation as well as the flexion angle of the knee joint in patients with reconstructed ACL, with rehabilitation accomplished in comparison with a group of people with no knee joint dysfunction. The influence of the angle of shank rotation and the angle of flexion of the knee joint on torque was assessed. Additionally, the results of the two groups were compared in order to evaluate the influence of rehabilitation process on the torque of the shank rotating muscles.

* Corresponding author: Mariusz Hrycyna, The Halina Konopacka University of Physical Education and Tourism, Staszica 1, 05-800 Pruszków, Poland. Tel.: +48 504 164 574, fax: +48 22 759 55 36, e-mail: mariuszhrycyna@op.pl

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The practical purpose of the study was to obtain information necessary for proper diagnostics of motor dysfunctions in patients with knee injuries.

2. Material and methods

The control group consisted of 171 men, the students of the Academy of Physical Education (AWF, Warszawa) aged 21.40 ± 1.94, weight 77.81 ± 6.00 kg, height 179.33 ± 5.83 cm. The men were not involved in any professional sports activities nor had any knee joint injuries. The study sample consisted of 16 patients with knee joint injuries and the reconstructed ACL. The ACL was reconstructed by single-bundle method. In 12 cases, the transplant was taken from semitendinosus muscle and in 4 cases it was taken from patella ligament. Average age was 28.13 ± 4.46, weight 84.44 ± 7.35 kg, height 178.25 ± 5.12 cm. The reconstruction was done one year at the minimum before measurement, and rehabilitation accomplished 2 years at the maximum after the surgery. Rehabilitation process was carried out by one group of therapists. The study group members participated in rehabilitation activities three times a week throughout 16 weeks. Having brought back the full knee mobility and stability range, the members of the study group attended the gym and practised according to the exercise schedule drawn up by the leading therapist. Once a month the progress was controlled. Individual training session lasted 90 minutes. Nine people had right knee ligament reconstructed and seven had the left one. In the study, the distinction between the healthy leg and the injured leg was made in order to evaluate the difference resulted from the surgical procedures.

Rehabilitation program was designed individually, depending on the potential and condition of the patient, before and after the surgery. All the members of the study group were subjected to a pre-defined rehabilitation schedule:

- pre-surgery period – bringing back the full movement range, optimum strength as well as proprioception,
- week 1–2, post-surgery period – cooling down the joint, isometric exercises, CPM,
- week 2–6, the period of regaining functions – increasing movement range, improving proprioception, regaining proper walk,
- week 6–9 – physiotherapeutic treatment, proprioception and muscle strength training in open and closed kinematic chain with accessories,
- week 9–12 – stretching, strength and coordination and endurance exercises with accessories, physiotherapy,
- week 12–16 – bringing back the full range of bending and straightening movements including over-straightening, improvement of intensifying, amount and dynamics of exercises in closed and open kinematic chain, stand-ups, bicycle, stepper,
- week 16–24 – preparation for returning to recreational and sport activities, intensifying strength and endurance training, increasing the weights, dynamic exercises in proprioception and coordination, functional tests,
- week 24 onwards – regaining full physical ability.

The aimt of the study was to measure the torque of the shank rotating muscles in healthy individuals and in patients with knee joint injuries at the selected angles of flexion of knee joint and the angles of shank rotation. This study may broaden the knowledge and the understanding of measurement of torque and its value distribution.

The measurements were carried out using a prototype testing device. The device was created by JBA company for the Department of Anatomy of UPE, Warsaw. This station fulfils all requirements for proper measurements of torque of muscles under static conditions. The construction of the device provides precise stabilisation of the body trunk, thigh and foot. A series of trial measurements was carried out in order to eliminate any possible defects of the construction.

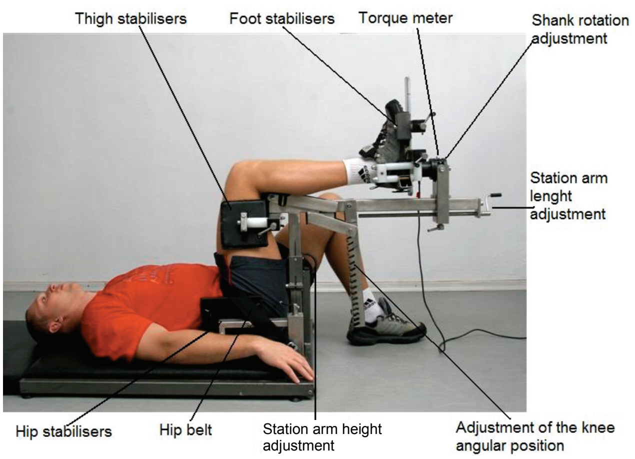
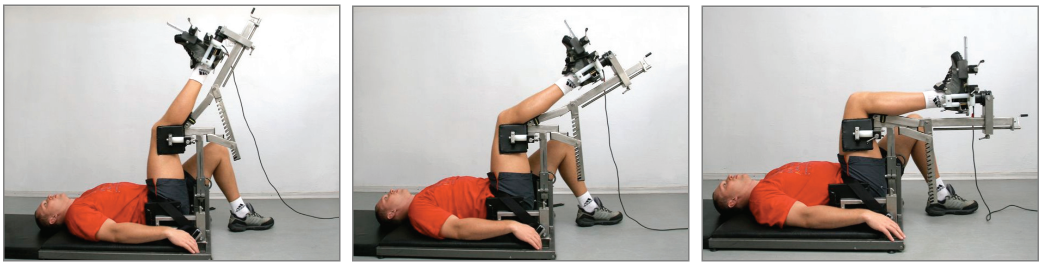


Fig. 1. A testing device for measuring the torque of the shank rotating muscles

Having done trial introductory studies and bibliography research on the correlation between the flexion angle and torque, the measurements (*Mm*) were carried out for the flexion angles under the following con-



30° 60° 90°

Fig. 2. Knee flexion angles (30°, 60°, 90°), straight lower limb as 0°

30° 60° 90°

Fig. 3. Shank positions at –30°, 0°, 45°

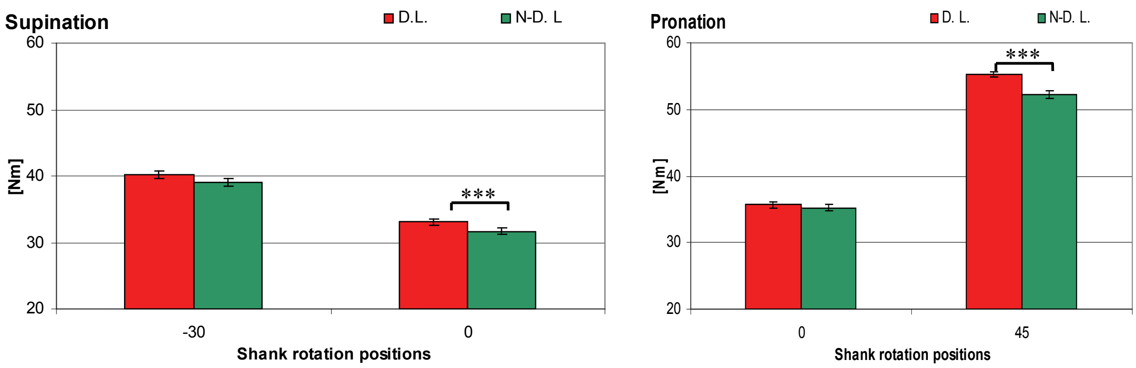
ditions: shank rotation (–30, 0, 45) and knee flexion (30°, 60°, 90°), assuming the straight limb as 0°, the inner rotation assumes a negative value [6].

The University Committee of the Study Ethics of UPE, Warsaw, confirmed the compliance of the study design with the study ethics requirements.

3. Results

In the control group, the maximum mean value *Mm* = 55.24 (Nm) was achieved in the dominant leg with pronation at the outside shank rotation angle of 45° and knee flexion angle of 30°. In the non-dominant limb, the highest mean value *Mm* of 52.30 (Nm) was achieved in the same position. When supinated, the maximum mean value *Mm* of 42.63 (Nm) was achieved in the dominant leg at the inside shank rotation angle of 30° and knee flexion angle of 90°. In the non-dominant limb, the highest average value *Mm* equal to 40.75 (Nm) was achieved in the same position.

The results in the control group show that the optimal angular position for maximal torque of the shank pronators is 45° of outside rotation, and for the shank supinators it equals 30° of inside rotation.



* – $p < 0.05$, ** – $p < 0.01$, *** – $p < 0.001$

Fig. 4. Mean torque values of supinators (left) and pronators (right) of the shank in dominant and non-dominant limbs at knee flexion angle of 30°. Control group

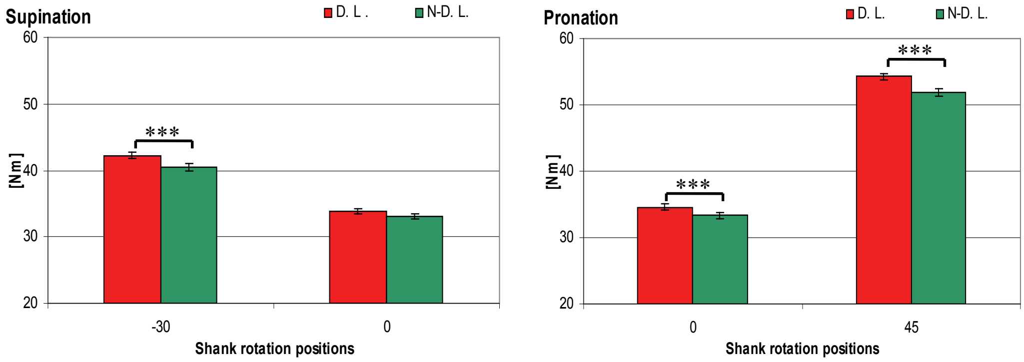


Fig. 5. Mean torque values of supinators (left) and pronators (right) of the shank in dominant and non-dominant limbs at knee flexion angle of 60°. Control group

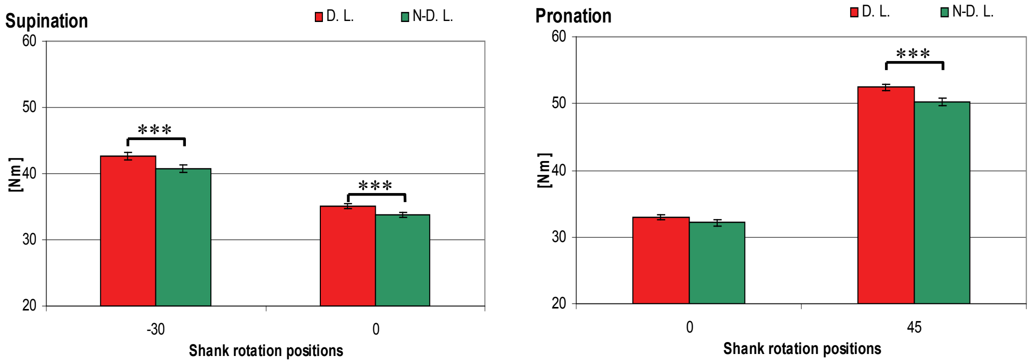


Fig. 6. Mean torque values of supinators (left) and pronators (right) of the shank in dominant and non-dominant limbs at knee flexion angle of 90°. Control group

Figures 4–6 present the mean values *Mm* of shank rotation in dominant (DL) and non-dominant limbs (N-DL) and statistical difference between respective average values.

The mean *Mm* values in the dominant leg were higher than those in the non-dominant one and in the majority of cases the difference was statistically significant ($p < 0.001$). The analysis of variance (ANOVA) in the control group was used to identify the dependent factors of torque values:

- sides: dominant – non-dominant (significance level $p < 0.001$),
- shank rotation angle (significance level $p < 0.001$),
- angular position of knee joint (significance level $p < 0.001$).

In the group with knee injuries, the maximum mean value *Mm* equal to 55.90 (Nm) was achieved in the non-injured leg with pronation at the outside shank rotation angle of 45° and knee flexion angle of 30°. In the injured limb, the highest mean value *Mm* of 46.96 (Nm) was achieved in the same position. When supinated, the maximum mean value *Mm* of 40.59 (Nm) was achieved in the non-injured leg at the inside shank rotation angle of 30° and knee flexion angle of 90°. In the injured limb, the highest average value *Mm* equal to 37.73 (Nm) was achieved in the same position. Figures 7–9 present the mean values *Mm* of shank rotation in non-injured (N-JL) and injured limbs (JL).

Except for one angular position, the mean *Mm* values in limbs with and without injuries were of no statistical significance $p < 0.05$.

The thorough analysis of the measurements revealed that the biggest difference between limbs was 5.95 Nm and it was observed at the outside shank rotation of 45° and knee flexion angle of 30°. The lowest values of the difference were noted at neutral shank position. In non-injured legs, the highest mean *Mm* value of supinators was by 12.31 (Nm) lower compared to pronators which achieved 23.3% (*Mm* of pronators is considered to be 100%). In injured limbs, this difference was 9.23, i.e., 19.6%. The differences between the strengths of supinators and pronators were close to those in the control group.

Comparing the mean *Mm* values at knee flexion angles of 30°, 60°, 90°, just as in the control group, it can be concluded that the bigger the knee flexion angle, the smaller the difference between torque values

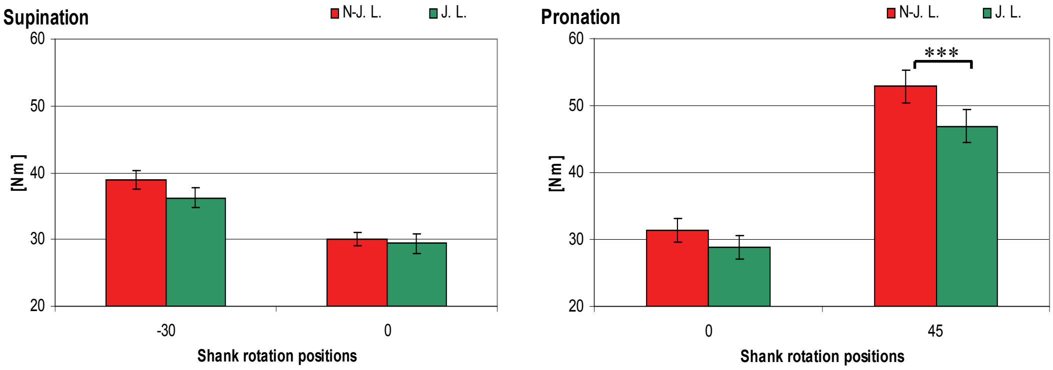


Fig. 7. Mean torque values of supinators (left) and pronators (right) of the shank in non-injured and injured limbs at knee flexion angle of 30°

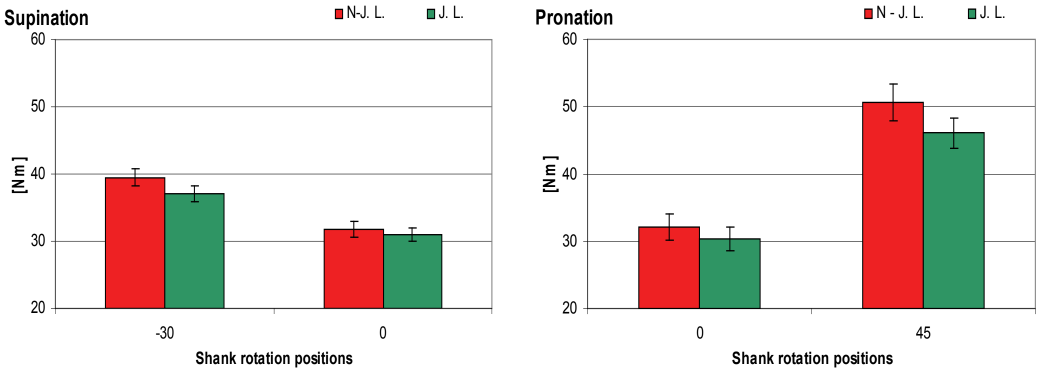


Fig. 8. Mean torque values of supinators (left) and pronators (right) of the shank in non-injured and injured limbs at knee flexion angle of 60°

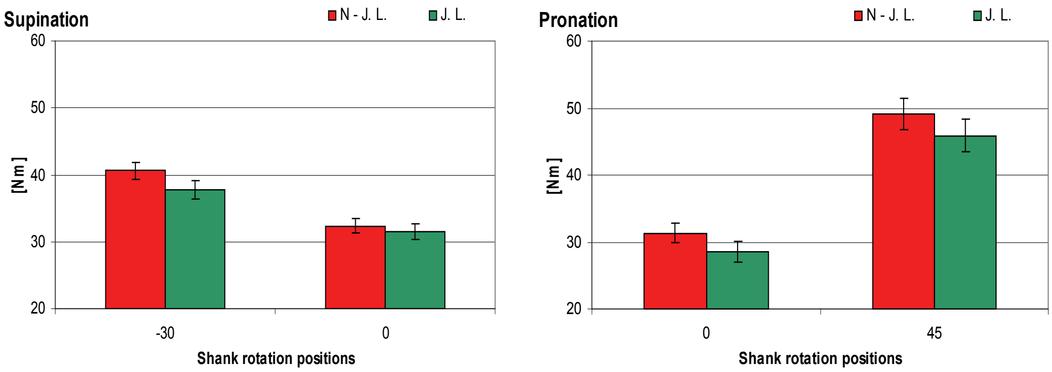


Fig. 9. Mean torque values of supinators (left) and pronators (right) of the shank in non-injured and injured limbs at knee flexion angle of 90°

of the shank pronators and supinators. The *Mm* values of pronators are lower when the knee flexion angles are wider, the opposite applies to the *Mm* values of supinators.

The analysis of variance (ANOVA) in the injured knee group was used to identify the dependent factors of torque values:

- shank rotation angle (significance level $p < 0.001$),
- do not depend on side: injured – non-injured,
- do not depend on angular position of knee joint.

One should present very careful and individual approach when the statistical analysis is considered because each patient was subjected to unique surgical procedures. The results of the examination of post-traumatic limb can be compared to the results obtained for the healthy leg. Only the overall analysis can be referred to the results of the control group in order to place a patient against the standard value of a feature.

Compared to the control group, the highest mean *Mm* value of shank pronators obtained in the sample group was lower for non-injured leg only by 2.34 (Nm) (4.2%), for injured leg by 5.34 (Nm) (10.2%), and the highest *Mm* value of shank supinators is lower for non-injured leg only by 2.04 (Nm) (4.8%), for injured leg by 3.02 (Nm) (7.4%) considering the results of the control group as 100%. The above mentioned *Mm* values are of no statistical significance ($p < 0.05$).

4. Discussion

The statistics on the rate of motor organ injuries show that the knee joint is one of the most frequently injured articulation of the human body [6], [12]. Therefore, there is a constantly growing interest in clinical studies of anatomy, biomechanics and pathology of the knee joint as well as in new methods of ligaments' reconstruction and its effectiveness [3], [8].

The effectiveness of a contemporary rehabilitation of the knee joint is assessed based not only on the improvement in the general strength as a result of a physical training, but also on the improvement in the range of muscle movement and proprioception [4], [10]. For those reasons physiotherapists are interested in becoming more acquainted with the functions and biomechanics of the knee joint, hence better and faster rehabilitation methods can be applied [1], [5], [8].

Additionally, in order to improve the training results, sports activists seek information on the possibilities and endurance limits of motor organ. An available professional literature on the functions and biomechanics of the knee joint concentrates on the torque values of flexor and extensor muscles of the knee joint which are responsible for swinging movements of the lower limb [2], [15], [16]. There is little data on the torque values of rotating movements which are responsible for a proper position of the foot against the ground and change the direction of the forces acting on the ligaments of the knee joint during locomotion [7], [9], [11]. The impairment of foot rotation results in restricting its range of movement. The muscles involved in the shank rotation protect joint capsule and ligaments. A proper function of joints results from complex anatomical and biomechanical structure of joint capsule and ligaments [6].

Anterior cruciate ligament (ACL) is one of the knee ligaments being damaged most often which leads to anterior instability of the joint. This injury is usually caused by a sudden change of the direction of the movement during rotation with stabilised foot and bent knee [6], [14]. At this moment rupture of cruciate and collateral ligaments occurs as well as injury to menisci. Specialists do not agree on some issues concerning the anatomy and functions of anterior cruciate ligament which leads to a need of further studies [12]. A general consequence of acute injuries to joint capsule and ligaments is a temporary or constant inability to go. In disciplines like football, handball or rugby, remarkably destructive factors may occur – a sudden change of movement direction at constant speed. A quotation from Widuchowski's paper: "The most common mechanism of the knee joint injuries in sportsmen is rotation movement at stabilised foot and bent knee" [14]. In this situation, it is very important to arrange an adequate and careful preparation of a sportsman by strengthening his motor functions of the lower limb. This may significantly reduce the risk of injury.

This study should prove that torque values of the shank rotating muscles of both limbs in the knee joint in rehabilitation group are comparable to those in the control group.

The difference between the mean torque values in injured and non-injured limbs is of no statistical significance. This confirms that the rehabilitation process was correct and careful and the physical exercises and their intensity were optimal. However, having compared the results of the group suffering from knee joint injuries with the results of the control group, no significant differences between them have been observed. Concluding, the torque is within common results.

Restoring full physical activity as well as practising sport depend not only on functional tests (muscle strength), but also on full movement range, good proprioception and coordination, proper muscle balance, absence of exudate or pain while being active [10].

WIT and MIROWSKI [16], while examining knee joint flexion and extension muscles' torque values of patients after ACL reconstruction (between the 9th and the 18th month after the surgery) and comparing them with the values in the control group, did not observe statistically significant differences in static extension and flexion muscles strength in the limb with or without injury.

CZAMARA [4] proved that as early as 21 weeks after ACL reconstruction, due to an adequate and proper rehabilitation, knee joint flexion and extension muscles' torque values can be evened out in comparison to a healthy as well as a control group.

5. Conclusion

In patients after ACL reconstruction and completed rehabilitation, no difference between torque values of injured and non-injured limbs were observed. This confirms that a properly carried out ACL reconstruction as well as individually designed rehabilitation process were correct and effective. Information on the current torque values of the shank rotating muscles in the control group and in a particular individual may significantly enhance the rehabilitation process of injured limb before and after surgery.

Acknowledgements

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