ORIGINAL ARTICLE

Isokinetic evaluation of the muscular strength of the thigh in military traumatic transtibial amputees

Évaluation isocinétique de la force musculaire de la cuisse chez les amputés Transtibiaux militaires traumatiques

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Abstract

Introduction-Aim: Lower limb amputation can lead to subclinical gait impairment secondary to muscle weakness. Hence the aim of our work, which was the instrumental assessment of isokinetic thigh muscle strength in traumatic military transtibial amputees.

Methods: This was a descriptive cross-sectional study carried out in physical medicine and rehabilitation department over a 6-months period. Our study included only military lower limb amputees caused by mine explosion. All patients had a functional evaluation (walking speed and the 2-minute walk test) associated to an isokinetic evaluation of the couple quadriceps(Q)-hamstring(H) on both lower limbs on the concentric mode at 90°/s, 120°/s and 180°/s.

Results: Forty patients were included. The mean age was 30.15 ± 7 years with male exclusivity. Muscle testing revealed no motor deficiencies, and all patients had thigh amyotrophy.

Functional evaluation showed a mean walking speed of 1.4 m/s ± 0.3 and a 2-minute walk test of 161 meter ± 24.6.

Q peak torque (PT) on the healthy side was greater than on the amputated side at all velocities with a significant association between PT (Q), PT(H) and Q muscle test and 2-min walk test. The ratio (H/Q) was higher for the healthy side for all velocities.

Conclusion: The quality of standing and walking depends on muscle strength of the lower limbs. Isokinetic assessment and instrumental rehabilitation should be systematically included in the management of military amputees.

Key words: Lower limb amputation, muscular strength, isokinetic, quadriceps, hamstring.

Résumé

Introduction-objectif: L'amputation d'un membre inférieur peut entraîner un trouble de la marche infraclinique secondaire à une faiblesse musculaire. L'objectif de notre travail était l'évaluation instrumentale de la force isocinétique des muscles de la cuisse chez les amputés transtibiaux militaires traumatiques.

Méthodes: Il s'agit d'une étude transversale descriptive réalisée dans un service de médecine physique et de réadaptation sur une période de 6 mois. Notre étude n'a inclus que des patients militaires ayant subi une amputation transtibale causée par l'explosion d'une mine.Tous les patients ont eu une évaluation fonctionnelle (vitesse de marche(VM) et test de marche de2minutes)associée à une évaluation isocinétique du couple quadriceps(Q)/ischio-jambiers(IJ)des membres inférieurs sur le mode concentrique à90°/s,120°/s et 180°/s.

Résultats: Quarante patients ont été inclus. L'âge moyen était de 30,15±7 ans, avec une exclusivité masculine. Le testing musculaire n'a révélé aucun déficit moteur et tous les patients présentaient une amyotrophie de la cuisse. L'évaluation fonctionnelle a montré une VM moyenne de 1,4 m/s±0,3 et un test de marche de2minutes de 161mètres±24,6.Le couple de pointe (PT) du quadriceps du côté sain était supérieur à celui du côté amputé à toutes les vitesses avec une association significative entre le PT(Q), le PT(IJ) et la force musculaire du Q et le test de marche de2minutes. Le ratio (IJ/Q) était plus élevé du côté sain.

Conclusion: La qualité de la station debout et de la marche dépend de la force musculaire des membres inférieurs. Une évaluation isocinétique et une rééducation instrumentale devraient être systématiquement incluses dans la prise en charge des amputés militaires.

Mots clés: Amputation membre inférieur, rééducation, isocinétisme, force musculaire

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Introduction

Under the control of the central nervous system, human movement takes place through complex and highly coordinated mechanical interactions on the musculoskeletal system. Any damage of these components such as limb amputation results in instability or inability to move [1].
A transtibial amputation (TA) is a burden on society because of its musculoskeletal sequels and functional impairment such as walking difficulties leading to limitation of movement activity and a participation restriction of lower extremity prosthetic wearers [2]. The inability to exert adequate force or tolerate the asymmetry under the sacrificed leg leads amputees to develop compensatory mechanisms through the uninjured leg. This load asymmetry leads to muscular asymmetry in the lower limbs, clinically manifested by muscle weakness and amyotrophy in the thigh of the affected limb [3]. However, these gait disorders can sometimes be subclinical, hence the importance of isokinetic assessment of the thigh extensor-flexor pair which provide an objective measurement tool [4]. These different aspects were not highlighted in the studies and therefore present a gap in the research because muscle strength has always been assessed subjectively by muscular testing and various isometric strength ratings. Add to that, few studies have looked at muscle strength in amputees and, more rarely, in victims of mine explosions. In fact, this is done in a population of healthy, athletic patients, free from pathologies that can affect muscle strength, which gives our study even more value and objectivity.
Hence the aim of our work which was to instrumentally assess the isokinetic strength of the thigh muscles on military traumatic transtibial amputees.

Methods

Type of study

This was a descriptive cross-sectional study carried out in physical medicine and rehabilitation (PMR) department in Tunis over a 6-months period between December 2021 and May 2022.

Study population

Inclusion criteria
• Patients who have had a TA caused by mine explosion.
• Patients regularly followed in the PMR department.
• Amputees who acquired the provisional prosthesis for at least one year.

Non-inclusion criteria
• Non-military patients

Exclusion criteria
• Patients who had bilateral lower limb amputation, or other than TA or associated upper limb amputation.
• Amputee patients who had another chronic or systemic pathology that could interfere with muscle strength.
• Any contraindication to the practice of isokinetic.

Study protocol

Isokinetic assessment was performed by the same evaluator following a standardized protocol that was applied to all patients [5].
In the first step, the evaluation process was explained to patients and a trial practice including 5 repetitions of the test was made.
The second step was a 10-minute warm-up on a treadmill at 2 km/h, incline 0°.
The third stage was a bilateral isokinetic evaluation of knee muscles: quadriceps (Q) and hamstring (H), in concentric/concentric mode for various velocities (90°/s, 120°/s and 180°/s). We always started with the healthy side and each patient performed 3 sets of speeds: 90°/90°-120°/120°-180°/180°. Each set consists of 10 repetitions of knee flexion extension with a rest period of 10 seconds between each set.

Assessment criteria

Main judging criteria
Isokinetic testing has made possible to analyze knee muscle contraction.
We assessed the peak torque (PT), the agonist/antagonist ratio and the muscle deficit in concentric mode.
The peak torque is expressed in Newton-meters (Nm) and corresponds to the maximum force moment developed during the movement.
The evaluation of muscle deficit in concentric mode is the difference in percentage (%) between the healthy and the injured side. This deficit is assessed on 3 scales [6]:
• No deficit < 15%
• Minor deficit 15-25%
• Major deficit > 40%

Secondary judging criteria
We performed a functional evaluation based on the monopodal balance, the walking speed and the 2-minute walk test.
The monopodal balance reflects the patients' physical condition as well as the state of the healthy limb. It allows classification according to Schoppen et al [7] into: impossible, possible with support, possible without support less than 10 seconds, possible without support more than 10 seconds.
The walking speed is assessed using the 10-meter Walk Test which measures the time taken by the patient to cover a 10-meter walk.
The 2-minute walk test is assessed by asking the patient to make as many round trips as possible. We set the starting point and asked the patient to walk the longest distance in 2 minutes in an obstacle-free area. After two minutes, we measured the distance covered in meters.

Statistical analysis

The data were analyzed using SPSS version 22 software. The quantitative variables were expressed as the mean with the standard deviations if the distribution is Gaussian or median (extreme) if the distribution did not follow a normal law. Qualitative variables were expressed as a percentage.
The population was tested by univariate analysis. Comparison of percentages on independent series was made by the Pearson chi-square test. When the application conditions of the chi-square test were absent, we used Fisher's exact test. The comparison of 2 means on independent series was made by the Student's T test for independent samples. The comparison of several means (>2) on independent series was made by the ANOVA test. When the validity conditions of the tests described above were absent, we used the Mann-Whitney U-test. The correlation between two quantitative variables was made by the Spearman test to calculate the correlation coefficient (r).
The level of significance in all statistical tests was set at 0.05.

RESULTS

We initially assembled 50 patients, of which 40 satisfied our inclusion criteria.

Sociodemographic characteristics

The median age was 27.5 years with extremes ranging from 22 to 49 year. All participants were male and had no notable pathological history. All our patients had regular physical activity before amputation and twenty-eight percent were involved in sport after amputation. Fifty-five percent have gone back to their professional activity with an average duration of 21±6months. The mean duration of the amputation was 45±18months. The average prosthesis wear per day was 12±1.5hours.

Physical examination

The mean body mass index (BMI) was 23.3kg/m²±2.8. Involvement was on the right side in 53% of patients. The amputation level was the middle third in 60% of amputees and the middle third-upper third junction in 13% of amputees. The shape of the stump was cylindrical 13% of patients and conical in 85%. The average length of the stump was 16.3cm±3.4. All patients had amyotrophy of the thigh. The difference in the perimeters of the thigh measured from the base of the patella was respectively 4.75cm±1.3 at 5cm, 5.45±1.2 at 15cm and 5.96±1.1 at 20cm. Muscle testing revealed no deficits.

Functional evaluation

Monopodal balance
Monopodal balance was possible without support for more than 10 seconds in 100% of cases.

Walking speed
The mean walking speed was 1.4 m/s±0.3 with extremes from 0.83 to 1.89 m/s.

The 2-minute walk test
The mean distance was 161meters ±24.6 with extremes from 0.83 to 1.89 m/s.

Isokinetic evaluation

Evaluation of the couple Q/H with velocity of 90°/s
Ninety-eight percent of patients had PT(H) and PT(Q) on the healthy side higher than the amputated side (Table 1). Ninety-five percent had a major deficit on Q and 2,5% of patients had a minor and no Q deficit.
On the healthy side, 98% had a PT(Q) higher than PT(H). On the amputated side 58% had a higher PT(H).

Table 1. Results of peak torque and muscle deficit in percentage of quadriceps and hamstrings

	Mean ± standard deviation			Minimum			Maximum		
Velocity	90°	120°	180°	90°	120°	180°	90°	120°	180°
H* on the healthy side	65,66 ±21,58	65,36 ±18,13	56,95 ±12,91	27,2	32,9	33,4	110,6	104,2	83,0
H* on the amputated side	34,94 ±13,92	32,26 ±13,68	28,80 ±10,75	10,1	10,0	11,8	66,3	59,6	55,1
H* deficit	44,35 ±18,45	50,24 ±16,35	48,56 ±14,20	-3,7	14,2	17,8	85,1	85,0	79,6
Q* on the healthy side	124,71 ±37,31	108,82 ±28,91	83,40 ±23,98	30,7	37,9	22,4	195,8	168,8	134,3
Q* on the amputated side	36,19 ±15,91	29,14 ±15,80	24,50 ±12,68	10,8	6,1	7,7	82,4	74,4	54,3
Q* deficit	68,43 ±17,97	72,76 ±13,50	68,12 ±20,09	-0,7	33,2	-5,8	89,9	91,1	91,2

***H** : hamstring ***Q** : quadriceps

On the healthy side ninety-eight percent of patients have an PT(Q) greater than PT(H). On the amputated side 50% had PT(Q) greater than PT(H).
The ratio was higher on the amputated side compared to the healthy side in all patients (p=0,563) at an angular velocity of 90°/s (Table 2).

Evaluation of the couple Q/H at with velocity of 120°/s
All patients had PT(H) on the healthy side higher than the amputated side and PT(Q) on the healthy side higher than the amputated side (Table 1).
Seventy-five percent had a major deficit on H and 98% on Q.

All patients had a higher ratio on the amputated side (p=0,159) (Table 2).

Evaluation of the couple Q/H at an angular velocity of 180°/s

All patients had PT(H) on the healthy side higher than the amputated side. Ninety-five percent of patients (95%) had a PT(Q) on the healthy side higher to the amputated side (Table 1).

A major deficit was found in H in 68% of patients and in Q in 95%.

On the healthy side, 90% had a PT(Q) higher than PT(H). On the amputated side 58% had a higher PT(H).

The ratio of the amputated side was higher than the healthy side in 97.5% of patients (p=0,001) (Table 2).

Our results were supported by the results obtained in

Table 2. Results of the hamstring/quadriceps torque ratios in percentages

	Mean ± standard deviation			Minimum			Maximum		
Velocity	90°	120°	180°	90°	120°	180°	90°	120°	180°
Healthy side	55,13 ±13,74	60,52 ±11,63	72,13 ±23,77	30,4	41,7	45	107,3	104,6	150,2
Amputated side	102,84 ±31,47	123,43 ±45,10	133,50 ±44,88	62,9	69,3	70,2	195,7	231,7	252,6

Univariate study of factors associated with isokinetic parameters

A significant association was found between the PT (Q) at all velocities and different parameters (Table 3).

Table 3. Results of the association of the PT(Q) at all velocities and different parameters

Parameter	PT (Q)
Age	**p=0,027**
Prothesis wear time	**$p<10^{-3}$**
Amputation age	**p=0,011**
Level of the amputation	**p<0.05**
Length of stump	**$p<10^{-3}$**
Amyotrophy of quadriceps	**$p<10^{-3}$**
Quadriceps testing	**$p<10^{-3}$**
Monopodal balance	**$p<10^{-3}$**
Walking speed	**$p<10^{-3}$**
2-minutes walk test	**$p<10^{-3}$**

*p= the level of significance

Discussion

The median age was 27.5 years old. All our patients had regular physical activity before amputation and twenty-eight percent were involved in sport after amputation. The average prosthesis wear per day was 12±1.5hours. Involvement was on the right side in 53% of patients. The amputation level was the middle third in 60% of amputees and the middle third-upper third junction in 13% of amputees. The shape of the stump was cylindrical 13% of patients and conical in 85%. The average length of the stump was 16.3cm±3.4. All patients had amyotrophy of the thigh. The monopodal balance was possible without support for more than 10 seconds in all patients. The mean walking speed was 1.4 m/s±0.3 and the mean distance at the 2-min walk test was 161meters ±24.6. The isokinetic evaluation found that the PT(H) and PT(Q) on the healthy side higher than the amputated side at all velocities and in most cases, the ratio of the amputated side was higher than the healthy side.

Amputees due to war trauma are younger than amputees due to another etiology [8]. This explains the young age of our population.

Only 27.5% of our patients practiced a sport and the same goes for the study made by Kars C et al. [9] in which 32% of amputees played sports. This may be due to complaints related to the residual limb, poor adaptation to the prosthesis, or to the patient's lack of motivation.

The average of daily wearing time of the prosthesis in our population was 11.83±1.5 hours which is close to the study made by Aytar et al. [10] which reported an average of 9.36±4.50 hours.

The involvement was on the right side in 53% of our patients, which is in line with the study of Ostojić L et al [11]. On the other hand, Ebrahimzadeh MH et al. [12] found a higher level of damage on the left side. This discrepancy is probably due to hazard. The stump should be cylindrical in shape and not conical [13] like only 12.5% of our patients. The optimum length of the stump should be between 12 and 15 centimeters below the joint line of the knee to ensure a good quality of standing and walking [14]. The average stump length in our study was 16.3cm±3.4, which is close to the results of the study by Isakov et al, in which the average length was 15.1 cm [15].

Monopodal balance was possible for more than 10 seconds in 100% of cases. It reflects the good physical condition of these young active military amputees [16].

Average walking speed is an interesting indicator of functional walking ability according to J.M. van Velzen et al [17]. It has been validated by Datta et al [18] for the evaluation of the amputee patient, and its reproducibility has been established by Boonstra et al [19].

Previous studies in the literature reported an average of 1.33 m/s [20-21] which is close to our results. Concerning the 2-min walk test, we found a mean distance of 161m which is close to the distance found by Gaunaurd I et al [20].

The concept of isokinetic was first described in the United States in 1967 by Hislop and Perrine [22]. It allows reliable, reproducible and objective measurement of muscle strength [23]. None of the assessment protocols used in the various studies has been standardized [6]. Our study showed that in concentric mode and for all angular velocities, the Q and H of the healthy limb were stronger than those of the amputated limb.

the studies of Isakov et al [24] and Pedrinelli et al [25]. However, the muscle deficit results in our study are higher than those reported in the literature. Indeed, Fraisse et al [26] had shown that PT for the knee flexors of the stumb was around 30 to 40° similarly to the healthy side and the normal population. In extension, the PT was around 60° of flexion on the healthy side and in the normal population [26]. The higher agonist/antagonist ratio for the affected limb testifies that the difference in strength between Q and H on the amputated side is more pronounced in the latter and pleads in favor of the previous conclusions. Our amputees presented in the healthy limb a higher PT(Q) then PT(H). Centomo et al [27] reported a lack of knee muscle co-contraction in TA which may explain this agonist-antagonist imbalance. However, this point of view was not anonymous in other studies. There were no differences between both lower limbs according to Sibley et al [28]. The results for the stump were different from the healthy limb, where the knee flexors had a greater PT and the muscle deficit was higher on the Q. Residual limb H have been shown to exhibit increased activation from initial contact to midcourse [29], with longer durations according to Powers et al [30]. Since the triceps is the main propulsive muscle when walking, its absence in amputees requires increased activity for the residual muscles [31]. Thus, the hip extensors become essential in paired walking and the glutes and H are protected from amyotrophy and subsequently muscle weakness by this new role [30]. Several studies have compared knee flexion and/or extension force between the residual and intact limb of unilateral transtibial prosthesis users [32]. The maximum isometric knee extension torque has been reported to be between 57 % and 70% lower in the residual limb compared to the intact limb. This deficit was also statistically significant in our sample. According to Isakov et al [15] , the PT values obtained in the muscles of the amputated limb were significantly lower compared to the muscles of the healthy limb ($p<0.01$).

New studies which could support our results seem to be necessary in this subject by including a larger number of war amputees. In fact, we found that the literature on this population was very limited.

Our study could be followed up with an isokinetic rehabilitation program aimed at improving stump muscle strength, in order to improve the gait pattern of this population of young, active prosthetic amputees, but also to avoid subsequent repercussions on posture. On the other hand, a postural assessment could be carried out on our patients to detect early postural disorders and their possible regression or intensification after isokinetic rehabilitation.

The aim of our study is to go far beyond ambulation and autonomy, and to achieve socio-professional reintegration with optimum quality of life.

Conclusion

In modern medicine, amputation is the last measure used when saving a limb becomes an almost impossible scenario. The loss of a limb lead to a disfigurement of the image of the body, lack of mobility and autonomy. The particularity of amputation caused by a mine explosion is that it occurs in a brutal and violent way in a young and active population. Isokinetic assessment of the residual muscles of the amputation stump allowed us to integrate these patients into an isokinetic rehabilitation program based on precise strengthening of the deficient muscles to ensure better prosthetization and therefore faster reintegration into socio-professional life.

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