ORIGINAL ARTICLE

IJPHY

DETERMINATION OF RISK FACTORS ASSOCIATED WITH WALKING DISORDERS AFTER ANTERIOR CRUCIATE LIGAMENT SURGERY WITH HAMSTRING GRAFT : A CONTROLLED MULTICENTER STUDY

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ABSTRACT

Background: Today, anterior cruciate ligament rupture is the most common injury in sportsmen and women, but it can also occur in sedentary subjects. Its treatment, always adapted to the patient's lifestyle, age, and will, often remains surgical. However, despite its frequency and universality, we still find gait disorders after the surgery and can up to several months or even several years after the surgery. Therefore, the present study is interested in determining the risk factors associated with gait disorders after an anterior cruciate ligament reconstruction (ACLR). This study aims to determine the risk factors associated with gait disorders after surgery with hamstring autograft. We are interested in the factors that may exist at 3 and 6 months postoperatively.

Methods: Two populations participate in this study, a healthy population and a population with ACLR subjects. The ACLR test group is divided into two subgroups, one with a post-operative delay of 3 months and the second with a delay of 6 months. All subjects are subjected to the same protocol; their gait on the treadmill was analyzed and evaluated by the device OptoGait®.

A united and varied analysis was first conducted, and then a multivariate analysis by adjustment method was carried out to eliminate potential confounding factors.

Results: Comparison of the results across populations in the unvaried analysis shows an absence of significant results ($p>0,05$); however, there are trends. The statistical results of the multivariate analysis showed interactions in the two subgroups of the ACLR population. At three months after surgery, there is a tendency for gait disorders to worsen in subjects with a BMI reflecting overweight, when an associated surgical procedure on the meniscus was realized, in subjects over 35 years old and in males subjects. In contrast, at six months after surgery, the worsening trend is only seen in the subgroups represented by subjects with BMI reflecting overweight subjects with meniscal repair associated with ACLR.

Conclusion: The present study results show certain factors tend to aggravate these gait disorders after ACLR with hamstring autograft; these factors are different depending on the post-operative delay.

Keywords: anterior cruciate ligament, walk, gait analysis, risk factors, hamstring graft, injury.

Received 19th September 2020, accepted 04th December 2020, published 09th December 2020

www.ijphy.org

10.15621/ijphy/2020/v7i6/844

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INTRODUCTION

Anterior cruciate ligament (ACL) tear is the most severe frequent ligament injury, with 65% of heavy injuries in sports [1]. Indeed, it occurs in 20% of cases when the knee undergoes an altercation during physical activity [2].

These anterior cruciate ligament ruptures are increasingly treated surgically to avoid the early appearance of associated pathologies such as meniscal pathologies or the early onset of osteoarthritis. Indeed, the risk of developing meniscal lesions or chronic knee instability is 20%. More than 50% of patients with an ACL deficiency show radiologic evidence of osteoarthritis of the knee ten years after their injury [3–5].

Today, we know that reconstruction can reduce the consequences of osteoarthritis and anteroposterior and antero-external instability [6].

Increasingly, reconstruction takes place in a relatively short time after injury.

Some authors consider that, as early as six months after an ACL rupture, one can observe symptoms of degeneration of the menisci without operative intervention.

Thus, they recommend reconstruction within a year of injury to avoid these complications [7].

In a sports population, the percentage of surgical reconstruction is 76.6% [8]. For example, France recorded 41,000 anterior cruciate ligament reconstruction operations in 2012, representing a real concern for public health and a high economic cost.

Often, despite ACL reconstruction, asymmetries persist in both lower limbs. These asymmetries are responsible for walking disorders, which appear from the first post-operative month to 6 months or even a few years after the surgery [9–16].

It is not uncommon for associated surgery on the meniscus to worsen these walking disorders [12,13]. A fortiori, we imagine that these walking alterations affect the musculoskeletal system's function and the kinematics of the operated limb and represent a danger for the walking parameters of the non-operated limb [17]. As they are described in the literature, these walking disorders can be responsible in the long term for the appearance of other disorders and injuries.

To offer the best possible rehabilitation to patients, it seems important to determine whether there are risk factors for gait disturbances following ACL reconstruction.

Thus, we may wonder about the risk factors for post-ACLR by hamstring graft walking disorders at 3 months and six months.

METHOD

Participants

The present study was carried out using two groups, an operated test group, and a non-operated control group. A total of 90 subjects were added to the study. The operated test group consists of 65 patients (age 31.53 ± 12.11 - BMI = 22.6 ± 3.42) and the control group of 25 patients (age 33.19 ± 11.06 - BMI = 25, 09 ± 3.64). Were included in the test group only patients over 18 years of age, having benefited from a reconstruction of the cruciate ligament before DIDT and able to walk without walking assistance at the post-operative period of 3 months or six months. Furthermore, the patients had to have a dry and non-inflammatory knee without hematoma and painless than two on the Visual Analog Scale (VAS). Were excluded from the two groups all the subjects who presented, on both lower limbs, neurological, dental and/or orthopedic disorders except for the surgical procedure. Likewise, subjects who had consumed psychotropic substances before the test were excluded.

In the control group, the inclusion criteria were the same as in the test group. The subject was also to present a gait without visible lameness and without walking aid.

Protocol

The protocol implemented was identical for all subjects participating in the study.

Each subject performed the walking test on the Elite 5000 treadmill from NordicTrack ® on which the OpToGait ® device *(Version 1.6.4.0, Microgate®, Bolzano, Italy)* presented by Microgate ® is installed. The latter device was connected to a Dell ® computer with a 256GB SSD, a 1TB hard drive, an intel core i7 ® processor, 8GB of RAM, and Windows 10 ®.

OptoGait ® is an optical detection system. It works with a transmitter bar and a receiver bar; it has an acquisition frequency of 1000Hz and a spatial precision of 1 cm.

Each of these bars contains 96 leds. These LEDs make it possible, for example, to measure the flight and contact time during the execution of a series of jumps, with an accuracy of 1/1000 of a second. The OpToGait device is validated for research because it has an ICC more significant than 95% [18], which allowed us to obtain reliable data for the measurements obtained.

During the test, each subject was allowed a 10-minute adaptation time [3] on the treadmill. This adaptation time made it possible to reproduce a walking pattern that was as natural as possible. During this adaptation period, the treadmill's speed was set to 4.0 km / h.

Once the elapsed adaptation, the treadmill is stopped, and gait analysis is started on OptoGait software. The OptoGait system already offers the selected test. The test is the following " Treadmill Walking 4km / h or 2.5mph ». The latter imposes a walking speed of 4 km / h.

Statistical analysis

Statistical analyzes were performed using R® software (R Studio, Version 1.2.5033 © 2009-2019 RStudio, Inc - 250 Northern Ave, Boston, MA 02210) after exporting the data to Excel® as well as to using the software Epi Info ™ I CDC.

Interference statistics have been carried out. The confidence level is preset such that C = 95% and the significance level

is α = 0.05.

The study includes 86 subjects; therefore, it is necessary to perform a normality test to account for the distribution of populations.

To compare each patient's demographic data, we, therefore, used the *Shapiro test* on each of the populations of the sample.

The study of the variances is carried out on each of the sample populations thanks to the *Chi2* test chosen for the qualitative values and *Mann and Whitney (Wilcoxon -Mann- Whitney)* for quantitative values.

Following the study of the descriptive variables, establishing the ORb (gross Odd Ratio) to objectify the walking disorders is a question.

The goal is to evaluate the risk of having walking disorders when one has undergone an anterior cruciate ligament repair.

First, the calculation of the ORa (adjusted Odd Ratio) was carried out by a varied uni analysis. Determining the ORa helps us shed light on the risk of having trouble walking. The unvaried analysis was carried out using the *exact Fischer test* which determines the threshold of significance.

For each stratum, to identify certain factors independently of other potential confounding factors, a multivariate analysis was carried out secondly using the Cochran-Mantel-Haenszel adjustment method.

RESULTS

Table I: Demographic table of the control and test groups (mean ± standard deviation)

	Control group (n = 25)	Test group (n = 61)	ρ-value
Age (a)	31.53 ± 12.11	33.19 ± 11.06	NS
BMI	22.66 ± 3.42	25.09 ± 3.64	0.004
Gender (M/F)	11/14	38/23	NS
Operated side (R/L)	∅	35/26	/

mean ±standard *deviation* *mean ± standard deviation*

a : years - kg : kilogram - m : meter - BMI : body mass index kg / m 2 - M / F : male / female - D / G : right / left - ∅⌋: no value - / : value cannot be calculated

Table II: Table listing the ORbs of the different groups among the test and control population.

	CT		∅⌋ TW		OR	95% CI	ρ⌋(b)
Control group	4	(16)	21	(84)	0.22	[0.0688-0.732]	0.0132
3 month test group	16	(50)	16	(50)	5.25	[1,4682-18,7728]	0.0114
6 month test group	12	(41.3)	17	(58.7)	3.7	[1.0102-13.5951]	NS
Test group (global)	28	(46)	33	(54)	4.45	[1.3662-14.5247]	0.0132

(b) NS = non-significant difference - Fischer test (Fischer exact)

TW = trouble walking

OR = Odd Ratio

CI = confidence interval

∅⌋ = absence

Table III: Results obtained for the test group at the operating time of 3 months.

	CT (n = 16)		∅⌋ CT (n = 16)		OR (a)	95% CI	ρ⌋(b)	ρ⌋(b), (CMH)
Age (c)								
18-25 years	4	(12.5)	6	(18.75)	0.67	[0.15-2.8209]	NS	NS
25-35 years	2	(6.25)	4	(12.5)	0.5	[0.0799-3.1276]	NS	NS
> 35 years old	10	(31.25)	6	(18.75)	1.67	[0.4888-5.6829]	NS	0.0124
BMI (c) 18.5-24.99	8	(25)	7	(21.9)	1.14	[0.3346-3.9041]	NS	0.0347
> 24.99	9	(28.1)	7	(21.9)	1.29	[0.3847-4.2969]	NS	0.0261
ACL reconstruction with hamstring graft (c)								
Isolated	8	(25)	12	(37.5)	0.67	[0.15-2.8209]	NS	NS
Associated meniscectomy	2	(6.25)	1	(3.1)	2	[0.1644-24.3289]	NS	0.0086
Associated meniscal suture	6	(18.75)	3	(9.4)	2	[0.4247-9.4184]	NS	0.0081
Gender (c) Women	3	(9.4)	7	(21.9)	0.43	[0.0938-1.959]	NS	NS
Man	13	(40.6)	9	(28.1)	1.44	[0.4824-4.3247]	NS	0.02

(a) adjustment for potential confounding factors: age, BMI, gender, associated lesions

(b) * ρ⌋<0.05; ** ρ⌋<0.01; NS = non-significant difference

(c) at the time of the CT scan or at the end of the survey for the control group CT = trouble walking

OR = Odd Ratio

(MH) = Cochran-Mantel-Haenszel X 2 test

∅⌋ = absence

The statistical analysis of Table II reveals an ORb of 0.22 and a statistically significant difference (ρ⌋- value < 0.05) for the control group as a whole.

The same is true for the 3-month subgroup with an ORb of 5.25 and the test group with an ORb of 4.45.

However, the analysis presented in Table I I I shows no statistically significant difference for the sub - group at 6 months for this group the OR b is 3.7.

For all the variables where the statistical analysis shows no statistically significant difference, there is nevertheless an interaction between the variable and the risk.

Multivariate statistical analysis reveals statistically significant differences for BMI, age (over 35) and being

Indeed, we can read that the ORa for a normal BMI is 1.14; against 1.29 for a BMI which reflects overweight.

Likewise, the Odd Ratio is 1.67 for subjects over 35 years old and 1.44 for men.

Table IV: Results obtained for the test group within 6 months postoperatively.

	CT *(n = 12)*		∅⌋ TW *(n = 17)*		*OR* (a)	*95% CI*	ρ⌋	ρ⌋ *(CMH)*
Age (c)								
18-25 years	3	*(9.4)*	3	*(9.4)*	1.42	[0.2431-8.2567]	NS	NS
25-35 years	5	*(15.6)*	9	*(28.1)*	0.79	[0.3103-3.0056]	NS	NS
> 35 years old	4	*(12.5)*	5	*(15.6)*	1.13	[0.2508-5.1213]	NS	NS
BMI (c) 18.5-24.99	3	*(9.4)*	10	*(31.25)*	0.42	[0.0961-1.8799]	NS	NS
> 24.99	9	*(28.1)*	7	*(21.9)*	1.82	[0.5305-6.254]	NS	0.0348
ACL reconstruction with hamstring graft (c)								
Isolated	6	*(18.75)*	12	*(37.5)*	0.71	[0.2075-2.4171]	NS	NS
Associated meniscectomy	0	*(0)*	2	*(6.25)*	/	/	NS	NS
Associated suture meniscal	6	*(18.75)*	3	*(9.4)*	2.83	[0.5891-13.6276]	NS	0.0166
Gender (c) Women	5	*(15.6)*	7	*(21.9)*	1.01	[0.2584-3.3623]	NS	NS
Man	7	*(21.9)*	10	*(31.25)*	0.99	[0.2939-3.3461]	NS	NS

(a) adjustment for potential confounding factors: age, BMI, sex, associated lesions

(b) * NS = non-significant difference

(c) at the time of the CT scan or at the end of the survey for the control group TW = trouble walking

OR = Odd Ratio

(MH) = Cochran-Mantel-Haenszel X 2 test

∅⌋ = absence

For all the variables where the statistical analysis shows no statistically significant difference, there is nevertheless a link between the variable and the risk.

The multivariate statistical analysis nevertheless reveals a statistically significant difference for the BMI when the subject is overweight.

Indeed, we can read that the ORa is worth 1.82 for a BMI, which reflects overweight.

Results analysis

The study will make it possible to compare walking disorders in patients operated on at three months and six months postoperatively. According to age, BMI, sex, and the associated surgical procedure, the analysis of the results makes it possible to assess the risk according to these criteria on the test group compared to the control group. This study's objective is not to evaluate the influence of the operative technique at DIDT on the spatio-temporal parameters of walking. Indeed, the goal is to allow clinicians to obtain information about the walking disorders that can occur and the risk factors that cause them.

From Table I's results, we can then say that being asymptomatic is a protective factor about the risk of having walking disorders, and this significantly.

Also, it can be said that being operated on for reconstruction of the cruciate ligament anterior in the general case is an aggravating factor in terms of the risk of having walking disorders. Indeed, the ORb is 4.45, which allows us to confirm the trend.

As for being operated on for an ACL reconstruction by hamstring graft after 3 months of operation, we note that this is also an aggravating factor in terms of the risk of having a gait disorder. But we can say that it is even more so than in the test group because the ORb is equal to 5.25 which allows us to say that the general risk is higher, and this always significantly. The unified and multivariate analysis of the test subgroup subjects at the post-operative period of 3 months is summarized in Table III.

The univariate analysis reveals no statistically significant difference for the variables studied. Indeed, all the r-values for the *Exact Fischer* test are greater than 0.05. There is therefore no link between the ORa and the variable studied. However we can say wether there is a tendency to protect, to the aggravation or if there is no effect. From the results found in Table III, we can then say that there is a tendency to worsen the risk of having a gait disorder at 3 months postoperatively when the subject is older than age 35 (ORa = 1.67), when the BMI indicates the subject's overweight (ORa = 1.29), when the subject has undergone an associated surgical procedure such as a meniscal suture or a meniscectomy (ORa = 2) or finally when the subject is a man (ORa = 1.44).

We will then determine if there are confounding factors for these variables, the confounding factors will be revealed by the Mantel-Haenszel adjustment method.

Here, we can then say that subjects with a normal BMI (ORa = 1.14) have no more risk of having a gait disorder than the healthy population.

On the other hand, for this analysis, we can still consider in a non-significant way that the female subjects (OR = 0.43), the subjects having undergone an isolated anterior cruciate ligament reconstruction (ORa = 0.67) and the subjects whose the age is between 18 and 25 years (ORa = 0.67) or 25 and 35 years (ORa = 0.5) present a tendency to protect the risk of having a walking disorder in the post-period 3-month operation.

From Table IV, it seems that gender tends to no longer have an effect on the risk of gait disturbance at 6 months (ORa = 1.01 for women and ORa = 0, 99 for men), it is the same for subjects whose age is over 35 years (ORa = 1.13).

On the other hand, we can say that there is a tendency to protect the risk of having a gait disorder for the subgroups representing subjects between 25 and 35 years old (ORa = 0.79), subjects having a normal BMI (ORa = 0.42); and subjects having undergone ACL reconstruction with

isolated DIDT (ORa = 0.71).

Nevertheless, it appears a tendency to worsen the risk of having a gait disorder when the subjects are aged between 18 and 25 years (OR = 1.42), when the subjects are overweight (OR = 1.82), and when there was an associated meniscal suture (ORa = 2.83).

Here we can note that the ρ-value of the OR was equal to 1 for subjects between 18 and 25 years old,

which reveals the non-incidence of age on the variable for this stratum.

The multivariate statistical analysis in Table IV enabled us, as for the previous group, to eliminate confounding factors if they exist.

The 6-month operating time test subgroup followed the same adjustment method as the 3-month group, the *Cochran-Mantel-Haenszel test.*

In this group, the statistical analysis revealed no difference for age, sex, subjects with a normal BMI and those who had an anterior cruciate ligament reconstruction in isolation.

Therefore, we can conclude that there is no interaction between the variables concerned and the gross risk expressed at 6 months (see Table II). Indeed, for these variables all ρ *(CMH)* are greater than 0.05. We note that the analysis shows a statistically significant difference for the variables concerning subjects with a BMI that reflects overweight (ρ= 0.0348) and subjects having undergone a meniscal suture associated with ACL reconstruction (ρ= 0.0166).

Regarding these last two variables, the Cochran-Mantel-Haenszel adjustment method therefore shows that there are interactions between the variable and the gross risk expressed at 6 months (see Table II). Here too, it turns out that these two interactions are confounding factors.

Thus, the risk of obtaining walking disorders after the post-operative period of 6 months amounts to the risk of ORa only for these two variables (see Table IV).

But the ORa is not significant, this allows us to say that at six months post-surgery, the risk is likely to reach the adjusted risk for these two variables.

DISCUSSION

In 2016, Sigward et al. [19] told us in a study that, clinically speaking, walking should normalize between 8 to 12 weeks after ACL reconstruction. However, many authors have reported walking disorders a few weeks after the operation, up to 12, 13, sometimes even 24 months [20–23].

The results found in the literature are not necessarily identical because of the difference in post-operative time of the subjects included and the gait analysis protocol as well as the device used. Indeed, many studies are carried out with a 3D gait analysis device.

Di Stasi et al. (2015) [15] were interested in the gait adaptations depending on the sex of the preoperative phase where they undergo a rehabilitation program and up to 6 months after ACL reconstruction.

At 6 months post-operative, the highlighted results show that the men present more asymmetry in their gait than the women. The study reveals a statistically significant value in men (ρ<0.001), indicating that the hip range of motion of the operated limb was smaller than that of the unoperated limb, it is the same for its maximum knee flexion range when walking (ρ<0.001). Asaeda et al. in 2017 [14] demonstrated the presence of walking disorders 12 months postoperatively and that differences could still be noted between men and women.

The walking disorders identified are not the same, but the two genders similarly present them and make their walking non-physiological at 6 months and 12 months postoperatively. The study even concludes by arguing that it is not safe for women to resume sport at 6 months with such walking defaults. Unlike them, there was no gait disturbance in women at 3 months and 6 months in the present study; however, the post-operative delay of 12 months was not analyzed for our part. Few studies report data on the influence of age on walking disorders after ACL reconstruction. However, De Oliveira et al. [16] show in their 2019 study that there is a difference between young adults and adults.

Following our results, we notice that at 3 months it is the subjects over 35 years who present a worsening tendency to present a gait disorder and at 6 months it is the age group 18-25 years.

This analysis may lead us to think that older adults are cautious and more alert at the start of their rehabilitation and perhaps take more time in terms of functional recovery and that young people, on the contrary, give goodwill at the start of rehabilitation but that weariness settles

gradually to measure.

Despite the scourge of overweight in the health field, no study links BMI and gait disorders after ACL reconstruction. Nevertheless, Pietrosimone et al. [10] in 2018 studied the associations between the body mass index and self-declared disability in people who had undergone unilateral reconstruction of the anterior cruciate ligament. The study is conducted through a questionnaire, which will give a certain IKDC (International Knee Documentation Committee) score.

Some studies analyze walking in overweight or obese subjects, but in healthy patients who have never undergone ACL reconstruction or any other damage to both lower limbs. Here, the literature agrees [24–26] that subjects with a BMI reflecting overweight or obesity present walking disorders both in terms of spatio-temporal benchmarks and qualitatively. Indeed, we notice adaptations of the above and underlying joints and the knee, slower walking, more extended single and double support times, and reduced joint moments. All these changes in the walking pattern are not found in a healthy population whose BMI does not reflect overweight or obesity.

Analysis studies of walking with weighted vests simulating overweight were carried out by Hartigan et al. [27,28]

respectively in 2017 and 2016, this time on operated patients.

The persistence of hip asymmetries (only for women) and the moment of knee extension (for both genders) are still apparent and even worsened with the weighted vest.

These two studies tend to show that regardless of the operating time, overweight generates walking disorders after reconstruction of the anterior cruciate ligament. Although the subjects are not overweight in the last two, the weighted vest simulates overweight and approximates it.

It is recalled that in the present study, the patients present gait disorders associated with a BMI reflecting overweight at 3 months and at 6 months postoperatively, which is in agreement with the literature.

However, it is essential to note that the BMI is not always revealing because many athletes have a BMI which reflects being overweight simply because the muscle mass is heavier than the fat mass.

A few authors have been interested in walking disorders and alterations in the knee's biomechanics after ACL reconstruction by hamstring graft associated with a meniscal lesion (partial meniscectomy or meniscal suture).

In 2016, Hall et al. [9] are interested in meniscal injury and seek to know if the latter modifies the biomechanics of gait and the knee's strength after ACL reconstruction with DIDT. In this study, the subjects have all been operated for 12 to 24 months and the associated meniscal lesions are only partial meniscectomies or meniscal sutures.

The study results do not allow us to demonstrate that the meniscal lesion associated with ACL reconstruction with hamstring graft is responsible for a gait disorder or a lack of strength in comparison with a population operated on for reconstruction of the ACL in isolation.

Capin et al. [12], in 2018, published a study following on from Hall et al.'s work on changes in gait biomechanics after ACL reconstruction associated with a lesion of the medial meniscus. In this study, the subjects participating in the study have had surgery for an average of 5.3 months.

The study results show that there is a link between the alteration of the spatio-temporal landmarks of walking and the meniscal suture (here medial) in comparison with a healthy population. Other information comes to the fore when Capin compares the group that received a partial meniscectomy with the group that received a meniscal suture. He notices that the partial meniscectomy group's subjects load the operated limb on the medial compartment of the knee. In contrast, the subjects of the suture group tend to load the contralateral, non-operated limb.

In 2019, Capin et al. (13) was interested this time in the consequences that may have on the biomechanics of walking in subjects who have had a partial meniscectomy or a suture two years after ACL reconstruction.

The study results show that the walking pattern is altered within two years after reconstruction associated with partial meniscectomy but not in the case of a suture associated with ACL reconstruction. The analysis of this study's results, which takes place on subjects with a post-operative delay of 2 years, seems to highlight the fact that meniscectomy would be more harmful in the long term than meniscal suturing. Indeed, one can suppose that the absence of meniscus, which alters the knee's stability, modifies the application of the constraints and could lead to unwanted cartilaginous lesions that would contribute to the alteration of our walking pattern.

From another point of view, Asaeda et al. (2017) [14], who studied walking defaults depending on gender concludes that, according to the current database, the differences between the sexes in the

occurrence of post-operatory osteoarthritis probably comes most likely from the occurrence of meniscal and ligament injuries instead of the specific difference in gender in the biomechanics of walking.

The results put forward by Capin (12,13) and his collaborators in 2018 agree with the results of the statistical analysis in the present study. Indeed, the post-operative delay is the closest to our study with 5.3 months, and they also find walking disorders in subjects who have benefited from an associated meniscal suture.

Limits

First of all, it is important to report the number of participants within each stratum, and we know that the sample size influences the significance of the results obtained. We can then wonder if these results could have been modulated with a larger sample.

Thus, we can affirm that the results of the present study are representative of a larger sample. First, it would be interesting to increase the number of subjects in the control group to balance each group optimally.

It would perhaps be advisable to carry out the study again while keeping the same selection criteria to maintain the same objective by increasing the subjects' cohorts to allow better stratification and more efficient analysis of the results.

Today there is no real consensus on the exercises offered in rehabilitation following ACL reconstruction by hamstring graft.

According to a standard protocol, all the LCA group subjects were operated on in the same clinic with three different surgeons. The post-operative surgical instructions given for the rehabilitation follow-up are specified and are the same for all subjects. This would limit several therapists' variability, even if they were then followed by different physiotherapists in their practice and did not all follow the same rehabilitation program.

In a study published very recently, Vascellari et al. (2020) [29] question the time delays we are often subjected to throughout ACL rehabilitation. The results of their study, performed primarily by orthopedic surgeons, indicate that functional landmarks are more appropriate than steps

based on time since operation to guide progression in post-operative rehabilitation after ACL reconstruction. Thus they describe "phases" of rehabilitation: an early phase, an intermediate phase and a phase of return to sport. To move from one phase to another, joint, muscular, neuromuscular and / or functional objectives are expected. The author does not specify whether walking is a criterion for moving to the next level.

As for walking, there is no specific recommendation in the literature to carry out its rehabilitation. However, each physiotherapist is entirely free to use the techniques that seem optimal, useful and necessary during rehabilitation to achieve his goals. In their study, Shi et al. (2019) [3] show that treadmill walking can reduce stride length and duration. On the other hand, it seems that it can increase the gait of the upper body and decrease the regularity of the gait during the swing phase.

One possible interpretation of these results would be that people tend to walk more cautiously to avoid the risk of falling and, as a result, neglect the coordination between gait and upper trunk when walking on the treadmill.

Indeed, in many studies carried out in the literature, the analysis of walking is done on the ground [12,15] or on a force platform [13,27,28], over a given distance (15) or not and at a speed determined by the subject [12,13,15,27,28].

Furthermore, subjects from the ACL group were all operated on using a reconstruction by hamstring graft. Indeed, one can wonder if the surgery used could influence walking disorders in the post-operative phase. In the literature, most studies agree that there is no significant difference between reconstruction with hamstring graft or with the Kenneth Jones method.

In a study published in 2019, Johnston reports no difference between the two operating modes concerning the spatio-temporal parameters of walking and that neither would seem to favor the early onset of acquired osteoarthritis in the post-operative phase [30].

Nevertheless, the biases presented remain inherent in this type of research for the most part and are acceptable. Because of the results and conclusions that remain in agreement with the literature, this remains relevant in the context studied.

CONCLUSION

The study's main objective was to determine the risk factors for gait disturbance following ACL reconstruction by hamstring graft at three months and six months postoperatively. Therefore, a non-randomized study was carried out by comparing patients who presented walking disorders at three months with a healthy population and patients who presented walking disorders at six months with this same healthy population. The comparisons were made according to variables that are identical in the two subgroups of the test group. Namely, the study compared the walking disorders according to the sex, age, the BMI of the subjects and finally, the presence of a surgical procedure associated or not to the reconstruction of the ACL.

Analysis of the results of subjects with a post-operative period of 3 months highlights many trends.

The altered gait is found in each stratum; however, the method highlights tendencies to worsen the risk of obtaining a gait disorder in males, subjects who have benefited from an associated surgical procedure, subjects over 35 years of age, and those with a BMI indicating overweight. An absence of a statistically significant difference is found during the analysis for the other variables, which means that the variables in question do not affect the risk of obtaining gait disturbances three months postoperatively.

On the other hand, we note that at six months, the results' analysis reveals a tendency to worsen the risk of obtaining a gait disorder only in subjects with a BMI reflecting overweight those having benefited from a meniscal suture.

An absence of a statistically significant difference is found during the analysis for the other variables, which can testify that the variables in question do not affect the risk of obtaining gait disturbances six months postoperatively.

The analysis of gait in subjects having benefited from ACL reconstruction by hamstring graft tends to show an alteration of the spatio-temporal parameters of long-term gait in patients with a BMI reflecting overweight and in subjects who have had an associated meniscal injury. Thus, it would be interesting to adapt our management to re-educate as well as possible these patients who are more at risk of getting walking disorders than others.

Also, the integration of an analysis of gait associated with a muscle evaluation, posture, and laxity of the transplant at different rehabilitation stages would make it possible to adapt the treatment with a view to sports recovery and avoid the onset of complications recurrence.

Furthermore, the use of tools such as Opto Gait ®, allowing us to analyze quantitatively walking and spatial and temporal parameters, should be seen as a useful device in rehabilitation and could be implemented in such protocols.

Whether qualitative or quantitative, the analysis of walking tends to show deficits that can persist for several years after ACL reconstruction. The rupture of the ACL targeting mainly a sports public, and in view of the new found interest in running, it is crucial to evaluate the walk in all its components for rehabilitation, as well as possible to prevent the secondary lesions which can occur following a poor walking regimen and running. All this obviously to improve the quality of the assessment and therefore the rehabilitative care of these patients.

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