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FACULTEIT GENEESKUNDE EN LEVENSWETENSCHAPPEN
master in de revalidatiewetenschappen en de kinesitherapie

Masterproef

Frontal plane hip kinematics in persons with a gluteus maximus transposition

Promotor :
Prof. dr. Annick TIMMERMANS

Copromotor :
Prof. dr. Kristoff CORTEN
De heer Robertus VAN DER STRAATEN

Pieter Colemont , Kobe Vinken
Scriptie ingediend tot het behalen van de graad van master in de revalidatiewetenschappen en de kinesitherapie

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Hasselt, 06/06/2017 P.C.

Alken, 06/06/2017 K.V.

Research context

In the second part of this two-part master thesis which is situated around the rehabilitation of musculoskeletal disorders of the hip we're going to evaluate the kinematics of the hip in the frontal plane during gait in subjects with a M. Gluteus Maximus transposition. Until now, there is nothing known regarding objective functional measurements or gait analysis in subjects with a M. Gluteus Maximus transposition. A M. Gluteus Maximus transposition is performed on subjects with chronic, irreparable deficiency of the hip abductor muscles associated with chronic trochanteric bursitis and spontaneous avulsion of the M. Gluteus Medius and Minimus (Whiteside, 2014). Causes of M. Gluteus Medius tears are:

- Chronic, non-traumatic rupture of the anterior fibers or the M. Gluteus Medius tendon (Kagan, 1999; Whiteside, 2014; Yanke, Hart, McCormick, & Nho, 2013)
- Femoral head fractures or hip osteoarthritis (Whiteside, 2014; Yanke et al., 2013).
- Avulsion: idiopathic (Whiteside, 2014; Yanke et al., 2013), after chronic bursitis (Kagan, 1999; Whiteside, 2014; Yanke et al., 2013) and after total hip arthroplasty (Whiteside, 2014; Yanke et al., 2013).

This master thesis is part of a larger study that includes functional outcomes (questionnaires) and motion analysis (gait and sit to stance). The study design and methods are drawn up in consultation with our promoter and co-promoter. The healthy controls are recruited from the study of drs. R. van de Straaten. He compared the movement of persons with knee osteoarthritis with healthy controls. He measured the kinematics of the hip, knee and ankle of the healthy controls. The measurement protocol was the same in both study's. Measurements of healthy subjects were executed at the motion lab of the KU Leuven, Belgium. Because this study is a part of a larger study, the acquisition of all the data was under supervision of by drs. R. van der Straaten. Furthermore, data processing, interpretation and the academic writing process was predominantly performed independently, under guidance of drs. R. Van der Straaten. The thesis is written according to the guidelines of the International Committee of Medical Journal Editors – ICMJE (2015).

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Frontal plane hip kinematics in persons with a M. Gluteus Maximus transposition

Abstract

Background: The M. Gluteus Maximus transposition is performed in subjects with chronic, irreversible damage of the abductor muscles of the hip associated with trochanteric bursitis and spontaneous avulsion of the M. Gluteus Medius and Minimus. Until now, there is nothing known regarding gait characteristics on subjects with a M. Gluteus Maximus transposition.

Objectives: The aim of this study was to investigate the frontal hip kinematics during gait in persons after M. Gluteus Maximus transposition, and to evaluate to which extent they are different from kinematics in healthy persons.

Participants: Ten healthy subjects and ten subjects after a M. Gluteus Maximus transposition were recruited.

Measurements: All subjects had to walk ten meters up and down to their own preferred walking speed. Data was measured with inertial sensors and assembled into gait cycle graphs of the hip movement in the frontal plane. The maximal abduction and the maximal adduction of these graphs were calculated for each step during gait. From this data, the average of the maximum values of the abduction and adduction angles and the range of motion (ROM) were determined.

Results: Subjects with a M. Gluteus Maximus transposition had significantly less maximal adduction (-5.26°), and significantly less total ROM (-6.5°) in the frontal plane compared to healthy controls (P=0.01). In addition, subjects with a gluteus maximus transposition reached their maximal adduction angle significantly later during the gait cycle (+14.98%) (P = 0.023) than healthy controls.

Conclusion: Subjects who have undergone a M. Gluteus Maximus transposition have a significantly reduced maximal adduction angle of the hip. The maximal adduction angle occurs later in the gait cycle compared to healthy controls. Furthermore, these patients have a smaller ROM of the hip in the frontal plane compared to healthy controls.

1 Introduction

Prevalence of M. Gluteus Medius tears is estimated at 20-22% in patients with hip osteoarthritis (OA). M. Gluteus Medius tears have been reported to occur more often in women compared to men at a ratio of 4:1 (Bunker, Esler, & Leach, 1997; Howell, Biggs, & Bourne, 2001). The incidence increases with age (Bunker et al., 1997; Howell et al., 2001; Kagan, 1999), and is influenced by history of trauma, osteoarthritis and femoral neck fractures (Lachiewicz, 2011). For people aged 60 or over these, abductor mechanism tears occur in 25% of women and 10% of men (Howell et al., 2001). Pain on the lateral side of the hip is usually a complex clinical complaint for which a differential diagnosis is required.

The M. Gluteus Maximus transposition is performed in subjects with chronic, irreversible damage of the abductor muscles of the hip which is associated with trochanteric bursitis and spontaneous avulsion of the M. Gluteus Medius and Minimus. In this surgical technique, the anterior portion of the M. Gluteus Maximus and the entire Tensor Fascia Latae (TFL) are transferred to the greater trochanter (Whiteside, 2014).

The presence of tears were mostly observed at the insertion into the greater trochanter of gluteus minimus, and at the insertion of the anterior third of M. Gluteus Medius (Bunker et al., 1997). There are several causes of M. Gluteus Medius tear possible: a chronic, non-traumatic tear of the anterior fibers of the M. Gluteus Medius tendon (Kagan, 1999; Whiteside, 2014; Yanke et al., 2013); femoral neck fractures or osteoarthritis or a spontaneous avulsion (Whiteside, 2014; Yanke et al., 2013) after a chronic bursitis (Kagan, 1999; Whiteside, 2014; Yanke et al., 2013) or after THA (Whiteside, 2014; Yanke et al., 2013).

Symptoms are lateral hip pain (Bunker et al., 1997; Howell et al., 2001; Kagan, 1999; McGonagle, Haebich, Breidahl, & Fick, 2015; Whiteside, 2014), abductor weakness (Bunker et al., 1997; Cates, Schmidt, & Person, 2010; McGonagle et al., 2015; Whiteside, 2014), a Trendelenburg gait (Cates et al., 2010; McGonagle et al., 2015; Whiteside, 2014) and pain when lying on the affected side (Bird, Oakley, Shnier, & Kirkham, 2001), these symptoms worsen over time (Kagan, 1999).

Motion capture systems (e.g. M0CAP) are considered as the gold standard in the clinical gait analysis, although but these systems are time consuming, expensive, require a specially equipped laboratory and motion can only be performed in a restricted area (Bolink et al., 2015; Zijlstra, Goosen, Verheyen, & Zijlstra, 2008). Alternatives to these advanced but clinically unavailable MOCAP-systems are inertial sensors (e.g. Xsens Technologies), also known as inertial measurement units ("IMU"). These IMU measure acceleration, angular acceleration and the magnetic field vector in the three-dimensional local coordinate system (Seel, Raisch, & Schauer, 2014). Inertial sensors are valid and reliable measurement systems for kinematic measurements of gait (e.g. range of motion) outside a gait laboratory (Bugane, Benedetti, D'Angeli, & Leardini, 2014; Reininga et al., 2011; Seel et al., 2014). Gait parameters being investigated in other studies are: walking speed, step time, stride length, cadence, lateroversion of the pelvic, thoracic motion, ratio, range of motion of the hip joint, double support phase and stand time(Bolink et al., 2015; Bolink et al., 2016; Hjorth et al., 2014; Martinez-Ramirez et al., 2013; Rapp et al., 2015; Reininga et al., 2013).

Until now, there is nothing known about subjective patient-reported outcome measures and an objective functional measurement (inertial sensor based gait analysis) in subjects with a M. Gluteus Maximus transposition. The aim of this study was to investigate the frontal hip kinematics during gait in persons after M. Gluteus Maximus transposition, and to evaluate to which extent they are different from kinematics in healthy persons. It is hypothesized that that subjects with a M. Gluteus Maximus transposition their maximum adduction angle would be greater than those of the healthy controls.

2 Methods

This study was approved by the ethics committee of Hasselt University and Ziekenhuis Oost Limburg on October 20, 2016. This study was a part of a larger study involving motion analysis (gait and sit to stance) and questionnaires.

2.1 Participants

The number of subjects cannot be based on comparable studies since it is a new surgical procedure. In this study, a total of 20 subjects were included, 10 healthy subjects and 10 subjects after an M. Gluteus Maximus transposition.

The inclusion criteria for the healthy controls are: age between 45 and 75 years' old, no orthopaedic or neurological problems at the level of the trunk and lower limbs and the ability to understand and speaking the Dutch language. The exclusion criteria for healthy controls are: depression, cognitive impairment and conditions that affect the normal movement.

There are also Inclusion criteria for subjects with a M. Gluteus Maximus transposition. These are: an age between 45 and 75 years' old, trochanter pain, positive Trendelenburg, M. Gluteus Medius tear, total hip arthroplasty (THA), M. Gluteus Maximus transposition and the ability to understand and speaking the Dutch language. The exclusion criteria for subjects with a M. Gluteus Maximus transposition are: neurological problems, other orthopaedic problems which can influence the kinematics of the lower limb and other comorbidities.

Healthy subjects were recruited through advertisements, flyers, and acquaintances. The subjects with a M. Gluteus Maximus transposition were recruited by the department orthopaedic surgery of "Ziekenhuis Oost-Limburg" (ZOL) led by Prof. dr. K. Corten.

If Subjects met the inclusion and exclusion criteria, they received an informational letter including, among others, a request to participate in the study. Subjects were included in the study if they had signed the informed form.

2.2 Procedure

Gait analysis was performed after a M. Gluteus Maximus transposition to compare the kinematics of the hip with healthy individuals. These measurements are conducted with the Xsens motion capture system in combination with video recordings. On healthy subjects, the same measurements are conducted.

In this study, all participants will perform the following task:

Walking:

All participants preformed a 10-meter walking test. The walking distance was therefore marked on the floor. Participants were instructed to walk up and down according to their own preferred walking speed.

The functional movement measurements were conducted in the motion lab of the KU Leuven for all healthy subjects. Measurements of all subjects with a M. Gluteus Maximus transposition were performed at the ZOL.

2.2.1 Instruments

Xsens (MVN Biomech, Xsens Technologies, The Netherlands)

Using the Xsens technology (Zhang, Novak, Brouwer, & Li, 2013) spatio-temporal and kinematic parameters can be measured during functional tasks. IMU's were placed on the head, sternum, bilateral on upper and lower arms, shoulders, pelvis, thigh (li, re), the tibia (li, re) and feet (li, re).

Video analysis

The performance of the tasks is recorded by a video recorder facing the frontal plane. These recordings allow us to document unpredictable and relate to the Xsens measurements.

2.3 Data-analysis

2.3.1 Data acquisition

The data was measured using the Xsens system and automatically stored on the computer by MVN studio. This data was analyzed in MATLAB and assembled into gait cycle graphs of the hip movement in the frontal plane (Figure 1). The maximum and minimum values (max abduction and max adduction angle) of these graphs were calculated for each step performed while walking 10 meters. From this data, the average of the maximum and minimum values was taken. These mean values were statistically compared to each other. Finally, the ROM is calculated by taking the sum of the average max abduction angle and the average maximal adduction angle.

2.3.2 Statistical analysis

Statistical analyses were performed using IBM SPSS statistics 24. Before between group comparison of the mean values of gait parameters (ROM, maximal hip abduction angle, maximal hip adduction angle, time of maximal hip abduction angle, time of maximal hip adduction angle, age, length, weight and BMI) between subjects with a M. Gluteus Maximus transposition and healthy controls, normality, homoscedasticity and equal variances were investigated. The normality was not met by any data set because only 20 participants were recruited. The data to be analyzed wasn't single because two data groups were compared. Because of the fact that the data was independent, a Mann-Whitney test has been used. All the data will be presented as a mean ± standard deviations (S.D.). A value of $p < 0.05$ was considered statistically significant.

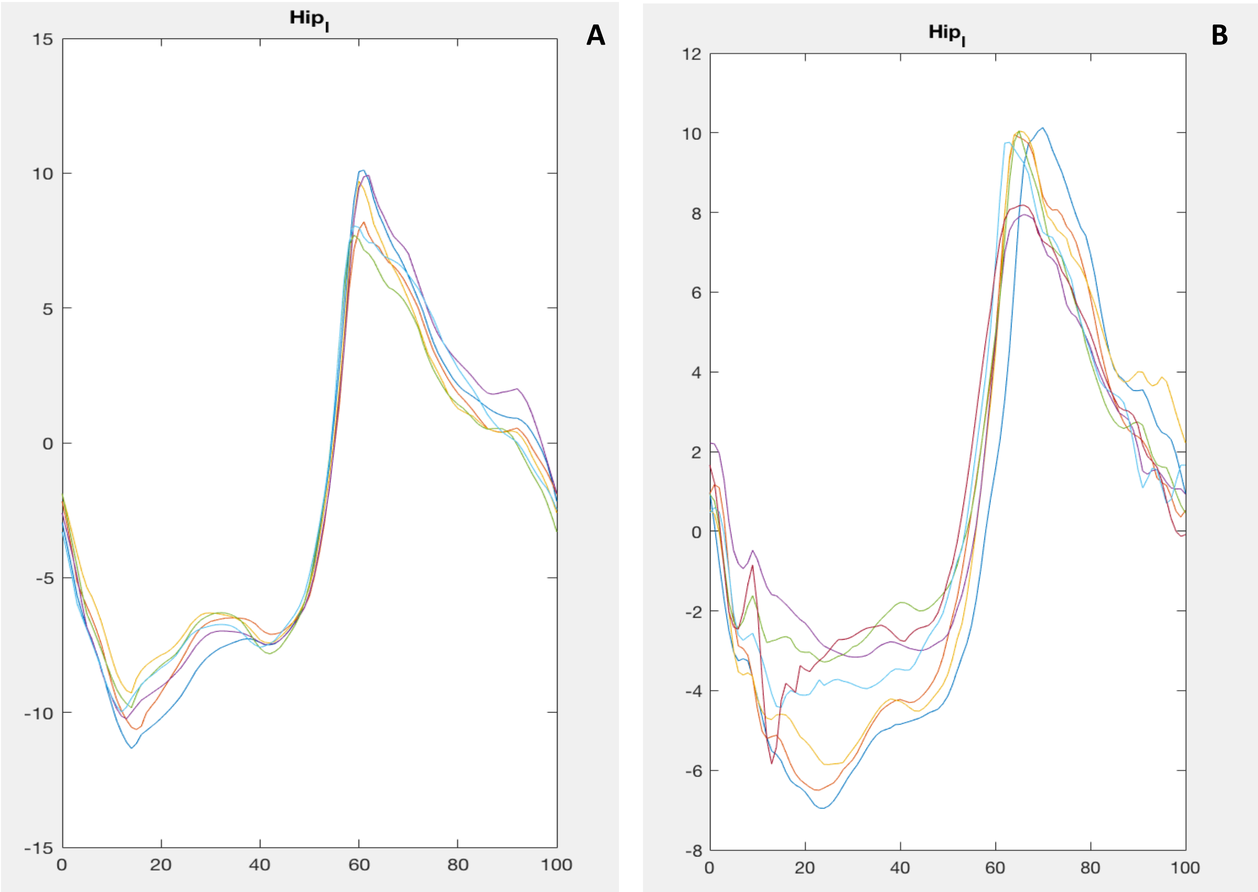

Figure 1: Kinematics of the hip

A: Kinematics of the hip in the frontal plane from healthy controls. B: Kinematics of the hip in the frontal plane from subjects with a M. Gluteus Maximus transposition. X-axis: percentage of the gait cycle, Y-axis: degrees.

3 Results

3.1 Patient characteristics

3.1.1 Age

The subjects with a M. Gluteus Maximus transposition had an age, mean (± S.D.) of 61 (± 9.9) years. The healthy controls had an age of 55 (± 3.5) years. No significant difference was found between both groups (P = 0.197).

3.1.2 Length

The subjects with a M. Gluteus Maximus transposition had a length, mean (± S.D.) of 1.68 (± 0.1) meter. The healthy controls had a length of 1.71 (± 0.1) years. No significant difference was found between both groups (P = 0.570).

3.1.3 Weight

The subjects with a M. Gluteus Maximus transposition had a weight, mean (± S.D.) of 76.9 (± 23.2) kg. The healthy controls had a weight of 73.8 (± 15.2) kg. No significant difference was found between both groups (P = 0.880).

3.1.4 BMI

The subjects with a M. Gluteus Maximus transposition had a BMI, mean (± S.D.) of 26.9 (± 6.0). The healthy controls had a BMI of 25.1 (± 3.2). No significant difference was found between both groups (P = 0.545).

3.2 Kinematics

A summary of the results can be found in table 1.

3.2.1 Maximal abduction angle of the hip

The subjects with a M. Gluteus Maximus transposition had a maximal abduction angle, mean (± S.D.) of 6.9 (± 4.0) degrees. The healthy controls had a maximal abduction angle of 8.2 (± 2.8) degrees. No significant difference was found between both groups (P = 0.821) (Table 1).

3.2.2 Maximal adduction angle of the hip

The subjects with a M. Gluteus Maximus transposition had a maximal adduction angle of 4.5 (± 3.0) degrees. The healthy controls had a maximal adduction angle of 9.7 (± 2.3) degrees. A

Statistically significant difference is demonstrated between both groups (P = 0.01) (Table 1), were the subjects with a M. Gluteus Maximus transposition had 5.26 degrees less maximal adduction.

3.2.3 Time of the maximal abduction angle during gait

The maximal abduction angle of subjects with a M. Gluteus Maximus transposition was measured at 64.41 (± 5.61) percent of the gait cycle. The maximal abduction angle of the healthy controls was measured at 62.13 (± 2.84) percent. No significant difference was found between both groups (P = 0.364) (Table 1).

3.2.4 Time of the maximal adduction angle during gait

The maximum adduction angle of subjects with a M. Gluteus Maximus transposition was measured at 30.51 (± 14.71) percent of the gait cycle. The maximum adduction angle of the healthy controls was measured at 15.53 (± 9.16) percent of the gait cycle. The subjects with a M. Gluteus Maximus transposition reached their maximal adduction angle 15% further, which significantly different (p= 0.023) compared to healthy controls (Table 1).

3.2.5 Range of motion of the hip in the frontal plane

Subjects with a M. Gluteus Maximus transposition had a range of motion of 11.3 (± 3.3) degrees. The healthy controls had a range of motion of 17.9 (± 2.7) degrees. A significant difference is demonstrated between both groups (P = 0.001) (Table 1), were the subjects with a M. Gluteus Maximus transposition had 6.5 degrees less range of motion.

Table 1: Summary of the results

A p-value of less than 0.05, we considered this to be a significant difference. The Mann Whitney test was used in this research.

Parameter	Healthy	Patients	P-value
maximum abduction angle	8.16 (± 6.19)	6.87 (± 4.03)	0.821
Time maximum abduction angle	62.13 (± 2.84)	64.41 (± 5.61)	0.364
maximum adduction angle	-9.71 (± 2.31)	-4.46 (±3.02)	**0.001**
time maximum adduction angle	15.53 (± 9.16)	30.51 (±14.71)	**0.023**
Range of Motion	17.86 (±2.7)	11.32 (±3.34)	**0.001**

4 Discussion

The aim of this study was to investigate the frontal hip kinematics during gait in persons after M. Gluteus Maximus transposition, and to evaluate to which extent they are different from kinematics in healthy persons. Despite, there is no literature available on gait analysis in subjects with a M. Gluteus Maximus transposition, it is hypothesized that their maximum adduction angle would be greater than those of the healthy controls. On the contrary, it was found that subjects with a M. Gluteus Maximus transposition walked with a lower maximum adduction angle compared to the healthy control group.

This is the first study to evaluate the gait cycle of subjects with a M. Gluteus Maximus transposition. The importance of this research is mainly focused on the effects of the surgical intervention on gait. The results show that subjects with a M. Gluteus Maximus transposition walk with less range of motion of the hip in the frontal plane, less maximal adduction angle of the hip and the maximal adduction angle was measured later during gait compared to healthy controls.

Because no prior studies exist on the gait cycle of patients with a M. Gluteus Maximus transposition it is one of this study's biggest strengths. Secondly, gait analysis is widely accepted as an objective criterion for physical functioning by which researchers and clinicians better understand the biomechanical changes in presence of hip OA and evaluate the functional success of THA and rehabilitation strategies (Lugade, Wu, Jewett, Collis, & Chou, 2010; Ornetti et al., 2010; Sariali, Klouche, Mouttet, & Pascal-Moussellard, 2014).

However, there were also limitations. The postoperative period wasn't standardized in the group of subjects with a M. Gluteus Maximus transposition. This makes it difficult to interpret the data after a certain postoperative period.

Furthermore, It would be interesting to compare preoperative and postoperative data for further research. This could be important in order to establish an objective view on the individual kinematic changes. Also, changes in the kinematics in other planes of motion (sagittal and horizontal plane) of the hip and changes in the kinematics in other joints of the lower limb after a M. Gluteus Maximus transposition are interesting to evaluate. Because there is no M. Gluteus Medius attachment, there is a change in movement strategy in the hip. This changed hip strategy also affects other joints of the lower limb. We know that weak and/or inadequate activation of the M. Gluteus Medius may permit greater knee valgus motion during dynamic tasks (Homan, Norcross, Goerger, Prentice, & Blackburn, 2013). A greater knee valgus angle is associated with a greater hip adduction angle.

Future research should also focus on the thoracic movement in the frontal plane, the movement of the pelvis in the frontal plane (pelvic obliquity) and the ratio between these two would needs to be analyzed. The importance of assessment of multiple lower limb joints is also known in subjects with hip OA. These subjects also have frequently weakened hip abductors. In Trendelenburg gait, a pelvic drop was seen on the non-weight bearing side during the swing phase with an increased adduction angle on the weight bearing side (Reininga et al., 2011; Watelain, Dujardin, Babier, Dubois, & Allard, 2001), whereby the pressure force moves laterally to the acetabulum (Amaro, Amado, Duarte, & Appell, 2007). The pelvic drop is frequently compensated by increased lateral leaning with the trunk. These subjects will move their center or mass (COM) to the supported leg, reducing the moment arm of the abductor muscles, resulting in a 'Duchenne gait' or 'abductor lurch' (Amaro et al., 2007). When pain occur during walking, a compensated trunk movement to the supported side can be observed. This significantly reduces the load in the hip joint, with a combined lateral pelvic movement (Schroter, Guth, Overbeck, Rosenbaum, & Winkelmann, 1999).

Finally, hip abduction strength does not influence the motion in the frontal plane of the knee and the hip (Homan et al., 2013). The only differences in frontal plane motion of the hip and knee occurred when subjects were tired (Homan et al., 2013). Abductors are more activated in subjects with weak hip abductors as compared to subjects with strong hip abductors. Compared to subjects with strong hip abductors, these findings suggest that subjects with weaker hip abductors have comparable eccentric resistance to hip adduction displacement but an increased neural drive to compensate for limited power (Homan et al., 2013). This can be the reason why a greater adduction angle for the healthy controls was found.

5 Conclusion

We conclude that subjects who have undergone a M. Gluteus Maximus transposition have a statistically significant lower maximal adduction angle of the hip. This adduction angle occurs later in the gait cycle than in healthy controls. Furthermore, these subjects have a smaller range of motion (ROM) of the hip in the frontal plane compared to healthy controls.

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7 Appendix

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Titel studie: Functionele uitkomsten na een M. Gluteus Maximus transpositie

u. kenmerk	o. kenmerk	eudract/B-nr	datum	kopie
	16/058U	B371201629563	20/10/2016	zie "CC"

DEFINITIEF GUNSTIG ADVIES

Geachte

Na inzage van de bijkomende informatie en/of aangepaste documenten met betrekking tot bovenvermeld dossier (uw schrijven van 14/10/2016) is het Comité Medische Ethiek van het Ziekenhuis Oost-Limburg van oordeel dat voorgestelde studie, zoals beschreven in het protocol, wetenschappelijk relevant en ethisch verantwoord is. Na raadpleging van de ethische comités van de andere deelnemende centra verleent zij dan ook een gunstig advies voor deze studie.

Dit gunstig advies betreft onder meer:

- Patiënteninformatie en toestemmingsformulier versie 1 dd. 14/10/2016
- Aanvraagformulier versie 1 dd. 23/06/2016

Zowel onze opmerkingen als de opmerkingen van de lokale ethisch comités werden voorgelegd aan de hoofdonderzoeker. Wij zijn van mening dat in de finale documenten voldoende rekening werd gehouden met deze opmerkingen.

Het Comité Medische Ethiek bevestigt dat ze volgens de ICH-GCP principes werkt.

Dit gunstig advies van het Comité houdt niet in dat zij de verantwoordelijkheid voor de geplande studie op zich neemt. U blijft hiervoor dus zelf verantwoordelijk. Bovendien dient u er over te waken dat uw mening als betrokken onderzoeker wordt weergegeven in publicaties, rapporten voor de overheid enz., die het resultaat zijn van dit onderzoek.

Ziekenhuis Oost-Limburg

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Graag wijzen wij u op de verplichtingen van de hoofdonderzoeker/opdrachtgever t.o.v. het Comité Medische Ethiek:

- De hoofdonderzoeker moet de inclusie van de eerste patiënt melden aan het Comité Medische Ethiek. Het definitief gunstig advies vervalt één jaar na datum van de definitieve goedkeuring wanneer er geen enkele patiënt geïncludeerd is.
- De onderzoeker moet jaarlijks een overzichtsrapport *(zie bijlage/website)* bezorgen aan het Comité Medische Ethiek.
- In geval van een ernstig ongunstig voorval moet men het Comité Medische Ethiek binnen de 7 dagen op de hoogte stellen.
- De hoofdonderzoeker/opdrachtgever bezorgt de documenten van een goedgekeurd amendement aan alle betrokken ethische comités. Opgelet: protocolwijzigingen die belang hebben voor de patiënt moet men in de patiënteninformatie opnemen.

Indien aan deze verplichtingen niet voldaan wordt, of de veiligheid van de patiënt in het gedrag komt, is het Comité Medische Ethiek wettelijk verplicht om op te treden.

Tenslotte verzoeken wij u ons mee te delen indien een studie wordt afgesloten of vroegtijdig onderbroken (met opgave van eventuele reden).

Met vriendelijke groeten

Dr. P. NOYENS
Voorzitter Ethisch Comité
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Titel studie: Functionele uitkomsten na een M. Gluteus Maximus transpositie

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Richting: **master in de revalidatiewetenschappen en de kinesitherapie-revalidatiewetenschappen en kinesitherapie bij musculoskeletale aandoeningen**
Jaar: **2017**

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Datum: **7/06/2017**