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Original Research

Dynamic simulation of flexor digitorum longus tendon transfer for flatfoot treatment

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ABSTRACT

Tibialis posterior muscle dysfunction leading to adult acquired flatfoot deformity. Tibialis posterior muscle dysfunction is commonly treated with a flexor digitorum longus tendon transfer to the tubercle of navicular bone. In recent years, the dynamic computer modeling has been used to predict the results of surgical and treatment. The aim of this study was to provide a dynamic computer model of flexor digitorum longus tendon transfer for predicting the outcome of flat foot treatment. In this study the 3D model of ankle joint, which consists of 29 bones and 12 muscles was developed in OpenSim. Using software, ankle plantar flexion moment, metatarsophalangeal joints moment and inversion moment of subtalar joint were drawn. After flexor digitorum longus tendon transfer, there were decreases ankle plantar flexion moment (6.7%), metatarsophalangeal joints moment (45%) and inversion moment of subtalar joint (34%). Plantar flexion moment reduction caused no significant changes in the ankle joint, but reduction in metatarsophalangeal joints could limit heel lift during propulsive phase in walking or running. A decreased inversion moment at the subtalar joint could alter the biomechanics of lower extremities.

Introduction

Musculoskeletal modeling of human locomotion, a branch of computational simulation of biological systems, has been growing rapidly in the past two decades, as demonstrated by the exponential increase in peer-reviewed publications. Musculoskeletal modeling shows great potential in orthopedic and biomedical engineering to improve diagnosis and treatment of patients with musculoskeletal disorders [1]. In this context, several software developed for Human movement and musculoskeletal modeling have facilitated the expansion of such applications. OpenSim, an open-source software platform, has been increasingly used as a reference tool for musculoskeletal modeling of locomotion. There has been an increase in subject-specific human musculoskeletal modeling with different levels of personalization for specific patient. Subject-specific modeling applications provide more accurate results compare to the generic models based on cadaver data [2]. Most clinicians have examined the neuromuscular excitation patterns and kinematic of movements before and after treatment interventions in many patients having abnormal movements [3-5]. The important variables to determine patient improvement are not generally measurable and using empirical data to express cause-effect relationships in complex dynamic systems is very difficult. Therefore, a theoretical framework combined with empirical data for estimating internal loading of the musculoskeletal system is required to determine how neuromuscular system disorders appear in abnormal movements. Finally, a scientific basis for the treatment programs of abnormal movements and prediction of treatment outcomes needs to be created. This framework would be obtained using dynamic computer simulations which describe the anatomical structure, elements of the musculoskeletal system, and dynamic kinematics of the joints. The cause-effect relationships between muscle forces, joint moments, and body movement pattern can be determined by dynamic computer simulation [4-6]. The tibialis posterior tendon is an important dynamic stabilizer of the foot arch and the strong inverter of the foot [2]. Tibialis posterior (TP) tendon dysfunction is observed in some situations like muscle weakness, stretching and putting the muscle beyond its functional length, or during muscle tendon rupture. This problem is extremely common in adult patients with acquired flatfoot [7]. Its symptoms include the medial longitudinal arch drop, forefoot abduction, and rearfoot eversion. Although biomechanical effects of the TP muscle inefficiency have not completely been recognized, this problem creates painful flatfoot throughout the lifetime [8]. Johnson and Strom (1989) were categorized the TP tendon dysfunction into three different stages. Stage 1 includes the TP tendonitis without visible deformity in the rearfoot, stage 2 includes flexible flatfoot deformity due to the TP muscle elongation, and stage 3 includes fixed rearfoot valgus and subtalar joint arthritis. The first and second stages modify with conservative management, the FDL tendon transfer, or Achilles tendon lengthen. The third stage can be treated using a brace, orthosis, or calcaneal osteotomy to prevent progression of valgus deformity in the ankle joint [9].

Numerous studies have been completed to transfer muscle tendons to treat certain disorders or dysfunctions [7,10]. Recently, satisfying results of muscle tendon transfer have been obtained to improve the biomechanics of human movement. For example, it can be referred to rectus femoris tendon transfer in treatment of Stiff-knee gait, hamstring tendon transfer in treatment of crouched-gait, and extensor carpi ulnaris transfer in treatment of wrist disorders [11-14]. Using the FDL tendon transfer combined with calcaneal osteotomy has been used to treat acquired flatfoot disorder [7, 8]. Due to the importance of ankle joint biomechanics changes after tendon transfer surgery and also create a scientific basis to predict treatment effects, computer models application seems necessary to conduct therapeutic interventions. Unfortunately, we found no study which has examined the biomechanical effect of the FDL tendon transfer. Therefore, the aim of present study was to evaluate biomechanical effects of the FDL tendon transfer with dynamic computer simulations using computer software OpenSim to treat the acquired flatfoot disorder.

Material and Methods

The FDL tendon transfer

To FDL tendon transfer, first a 5cm incision is made from the tip of the medial malleolus to just past insertion tendon of tibialis posterior (TP) muscle. Then, the FDL tendon which places below the TP tendon is identified. Finally, the FDL tendon is cut and transferred to the navicular tuberosity which is the attachment site of the TP muscle [7,8]. Using OpenSim software, the FDL tendon transfer from the metatarsal area to the third phalanx is deleted and remained tendon is attached to the navicular tuberosity.

Ankle joint model

It is important to create an ankle joint model before operating the FDL tendon transfer to determine a scientific basis for planning and anticipating treatment consequences. In this area, using dynamic computer simulation would be as a tool having great contribution potential. The dynamic computer simulations have to be implemented before the FDL tendon transfer to determine surgical plans and predict treatment effects. For this purpose, a modified right ankle joint model generated by lower extremity model (Gait2354_Simbodys.osim) of OpenSim software was used for the FDL tendon transfer. This software was developed with open access by Delp and his colleagues in the Biomedical Laboratory of Stanford University [3,6,7,15,16]. This model has a good validity and reliability because it made using experimental data with enough sample size. Also, this model has commonly accepted and widely used in some previous studies[4,17]. The detail information of the model (like effect of body weight, contact forces among neighboring bones and so on) is mentioned in the official website (www.simtk.org). However, we did not report this information because it may not be relevant to the aim of our study.

An OpenSim model represents the dynamics system of rigid bodies and joints acting upon forces to produce movements. An OpenSim model file is made up of components corresponding to parts of the physical system. These parts are bodies, joints, forces, markers, constraints, contact geometries, and controllers. In order to initiate the procedure of modeling, it is necessary to define the set of rigid bodies representing the system. The groups of bodies and the relationship between them have to be defined. To specify the model, the forces that apply to the model must also be defined. Forces can include muscles, optimized linear or moment actuators, and springs. Muscle properties (e.g., maximum isometric force, optimal fiber length, tendon slack length, pennation angle, activation time constant, and deactivation time constant) are considered at force definition step. To characterize muscle properties, muscle geometry paths must also be defined for each muscle in the model by using a set of path points. Prepared ankle joint model consists of 29 bones (made up six bone groups as the femur, patella, tibia and fibula, talus, calcaneus and metatarsal group, and phalanges) and 11 muscles (made up four muscle groups as plantarflexor, dorsiflexor, inverter, and evertor muscles).

The lateral, anterior, medial, posterior and superior views of the ankle joint model are shown in Figure 1, respectively (left to the right). In this figure, lines show 11 muscle pathways and dots show locations of 52 muscle attachment points defined in the model. Names, functions, and locations of attachment points for any muscle defined in the model are listed in Table 1. The FDL tendon has eight attachment points defined in the model. The first and second points are on the tibia, the third is on the calcaneus, the fourth is on the navicular bone, the fifth is on the third metatarsal, the sixth is on the second tarsal of toe, and the seventh and eighth are on the third tarsal of toe (see the Table 1 and Figure 1). The model has three degrees of freedom which the first is dorsal/plantar flexion of the ankle joint, the second is inversion/eversion of the ankle joint, and the third is flexion/extension of the foot phalanges. The three moments including of net isometric moment of the ankle plantarflexors, net isometric inverter moment of the subtalar joint, and net isometric plantarflexion moment of metatarsophalangeal joints were chosen to be discussed. These three moments are the most important variables in the ankle joint and the effect of other moments and variables is rare and negligible. Furthermore, these three moments are related to the FDL muscle moment which is the most important muscle of our study.

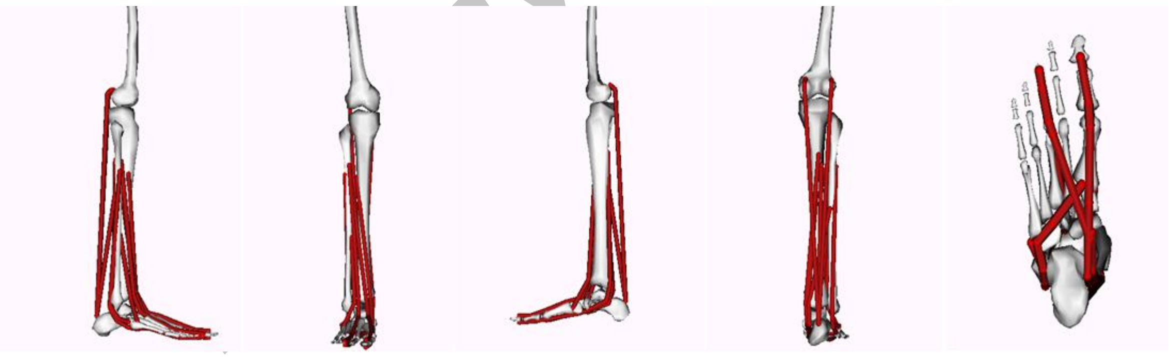

Figure 1. Lateral, anterior, medial, posterior and superior views of the ankle joint model, respectively (left to the right).

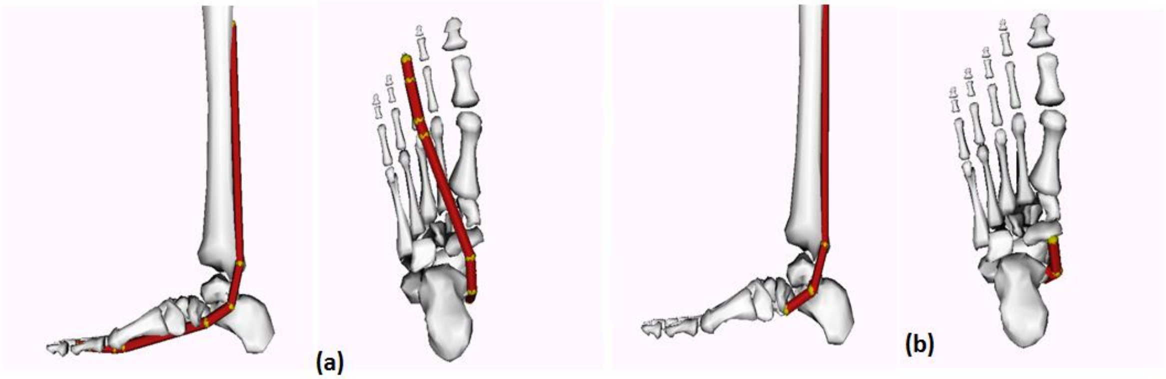

Figure 2. The FDL tendon transfer: (a) the medial and inferior views of the FDL muscle before transfer; (b) the medial and inferior views of the FDL muscle after tendon transfer.

Table 1. Name, actions, and muscle attachment points defined in the model.

Muscle name	Muscle functions	Muscle attachment points
A. Plantarflexor group		
1. Flexor digitorum longus	Plantarflexion and inversion	Ti, Ti, Ca, Na, Me3, Ph2, Ph3, Ph3
2. Flexor hallucis longus	Plantarflexion and inversion	Fi, Ti, Ca, Cu1, Me1, Ph1, Ph1
3. Gastrocnemius medial	Plantarflexion	Fe, Fe, Ti, Ca
4. Peroneus brevis	Plantarflexion and eversion	Fi, Fi, Fi, Ca, Me5
5. Peroneus longus	Plantarflexion and eversion	Fi, Fi, Fi, Ca, Me5, Me3, Me1
6. Soleus	Plantarflexion	Ti, Ca
7. Tibialis posterior	Plantarflexion and inversion	Ti, Ti, Ca, Na
B. Dorsiflexor group		
1. Extensor digitorum longus	Dorsiflexion and eversion	Fi, Ti, Cu3, Me3, Ph3, Ph3
2. Extensor hallucis longus	Dorsiflexion and inversion	Fi, Ti, Na, Me1, Me1, Ph1, Ph1
3. Peroneus	Dorsiflexion and eversion	Fi, Ti, Me5
4. Tibialis anterior	Dorsiflexion and inversion	Ti, Ti, Cu1

Fe: femur,Ti: tibia, Fi: fibula, Ta: talus, Ca: calcaneus, Na: naviculare, Cu: cuneiforme, Me: metatarsal, Ph:phalanges

Results

The net isometric plantarflexion moment of the ankle joint

Figure 1 shows the net isometric moment of the ankle plantarflexors before and after the FDL tendon transfer. In the Figure, positive and negative values represent the ankle dorsiflexion and plantarflexion joint angles, respectively. The negative moment value indicates that moment is the ankle joint plantarflexion. The peak value of the ankle dorsiflexion occurs at 12° and 50% of gait cycle before the propulsion time [18,19]. Peak moment of plantarflexion before and after the FDL tendon transfer was respectively -224 Nm and -209 Nm (6.7% decreased). At the end of stance phase followed by the push-off time, a rapid contraction of plantarflexor muscles begins. Peak plantarflexion occurs at -14° and at the early of swing phase. In this angle (4.5°), produced peak plantarflexion moment is -260 Nm which decreased to -244 Nm after the FDL tendon transfer at the same angle (6.15% decreased).

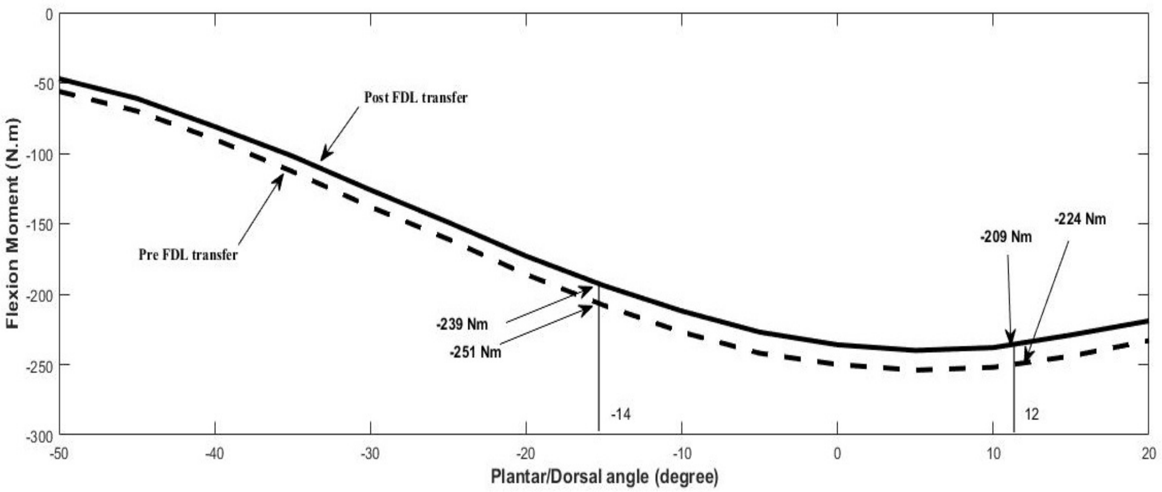

Figure 1. The net isometric moment of ankle joint plantarflexor muscles before and after the FDL tendon transfer

The net isometric invertersion moment of the subtalar joint

Figure 2 shows the net isometric inverter moment of the subtalar joint before and after the FDL tendon transfer. Positive and negative values represent eversion and inversion angles in the ankle joint, respectively. The positive moment value indicates to the ankle joint inversion. During the stance phase of walking, this joint has 1° to 3° eversion which the peak occurs in 30% to 40% of the gait cycle. It has also 5° to 7° joint inversion which the peak is in 50% to 60% of the gait cycle [19,20]. In 2° eversion position, the moment value would be about 48 Nm and 34 Nm respectively before and after the FDL tendon transfer (28.23% decreased). In -6° inversion position, the moment value would be about 12 and 90 respectively before and after the FDL tendon transfer (35.34% decreased).

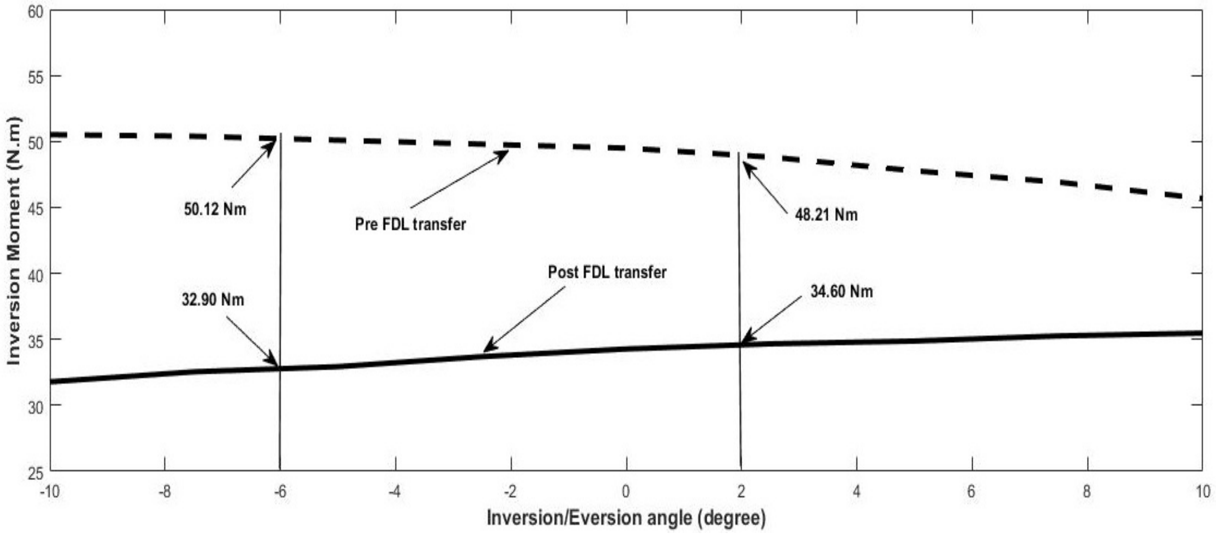

Figure 2. The net isometric inverter moment of subtalar joint muscles before and after the FDL tendon transfer

The net isometric plantarflexion moment of the metatarsophalangeal joint

The FDL muscle actions include of ankle joint plantarflexion, foot inversion, and digitorum flexion from the metatarsophalangeal and interphalangeal joints. Figure 3 shows the net isometric plantarflexion moment of metatarsophalangeal joints before and after the FDL tendon transfer. The positive degree of metatarsophalangeal joints indicates to joint dorsiflexion and the negative moment value indicates to the joint plantarflexion moment. In the stance phase of gait, the flexor muscles of metatarsophalangeal joints are responsible to control dorsiflexion action of this joint. Under the Heel-contact time and just before the early swing phase, metatarsophalangeal joints have 45° dorsiflexion passively [21-23]. In this angle, the peak moment value would be about -27 Nm and -15 Nm respectively before and after the FDL tendon transfer (42.54% decreased). In the Push-off time, the metatarsophalangeal joints have 25° dorsiflexion passively [13,14,24]. In this angle, the peak plantarflexor moment value would be about -30 Nm to -16 Nm respectively before and after the FDL tendon transfer (45.24% decreased).

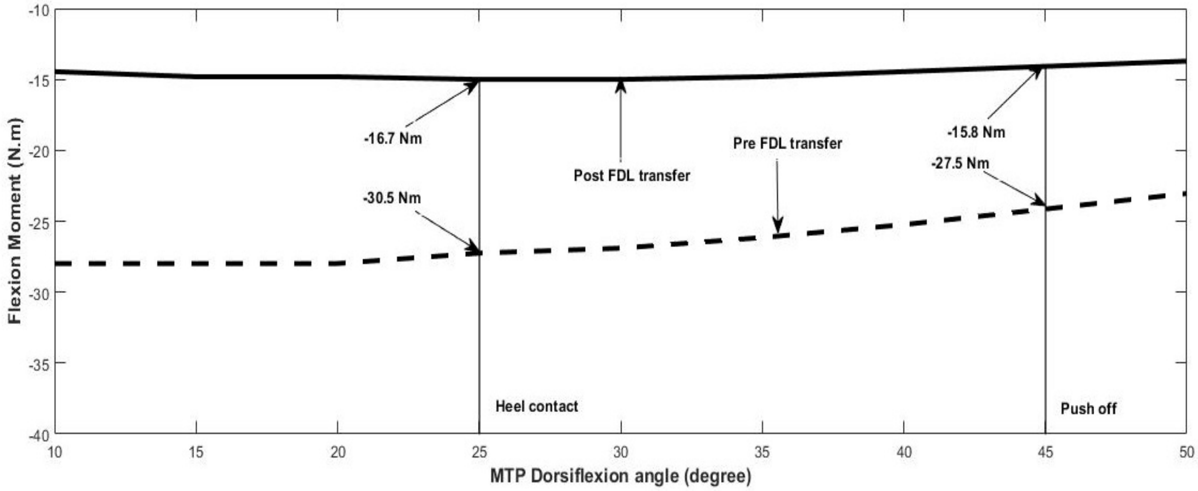

Figure 3. **The net isometric plantarflexion moment of metatarsophalangeal joints before and after the FDL tendon transfer.**

Discussion

The aim of present study was to evaluate biomechanical effects of the FDL tendon transfer with dynamic computer simulations using computer software OpenSim to treat the acquired flatfoot disorder. The FDL tendon transfer is a general approach for the treatment of painful flatfeet in adults [8,25,26]. Any change in the FDL tendon junction can affect the function of the foot joints. The aim of present study was to model the effect of the FDL tendon transfer on the foot joints moment. Ankle dorsiflexion occurs in the stance phase in which plantarflexor muscles control leg forward motion passively as a result of tibia motion on the foot [15]. As seen in the Figure 1, the FDL tendon transfer did not significantly change ankle plantarflexion function because there are powerful gastrocnemius and soleus muscles in the posterior of the leg [14]. In a normal situation following the FDL tendon transfer and assuming 7% decrease in the plantarflexor moment, other plantarflexor muscles can compensate this decreased moment with a slight increase in their activity.

During walking, the inverter moment helps foot supination to lock mid-tarsal joints and provides a strong lever for preparing the foot to force effectively in the later stance phase. The subtalar joint inversion is also critical to rotate the tibia on the foot [12,19,27]. Regarding the importance of inverter moment for body propulsion, decrease in this moment by 28% to 34% would change most lower extremity biomechanics. However, it may not be seen a significant change occurs during gait of the patient when a relative increase in other muscles activation and compensation the resulting moment and education of patient to prevent muscle fatigue.

According to the Figure 3, with cutting the FDL muscle and attaching it to the navicular tuberosity and reduction about 42% to 45% in the plantarflexor moment, the biomechanical function of the metatarsophalangeal and phalangeal joints would be faced with a problem. Although the FDL muscle action in open kinetic chain (OKC) movements is flexion of the foot phalanges, the action in closed kinetic chain (CKC) movements is stability and resistance of foot phalanges against ground reaction forces, which cause extension or dorsiflexion of phalanges and mid-foot during movement [18]. After the FDL tendon transfer, dorsiflexion in the phalangeal joints takes place in higher value and it may limit heel rising with disruption of foot mechanisms during walking [18,28]. In this situation, dorsiflexion in the metatarsophalangeal joints is increased and consequently, plantar fascia, connected from one side to this joint and the other side to the calcaneus, is strained. This mechanism would restrict heel rising during movement and gait pattern [18,27,28].

During walking and running, high reaction forces (30% to 100% of body weight) is imposed to the metatarsophalangeal joints [20]. These forces produce bending moment on these joints. In absence of the FDL muscle, support and continuity of imposed forces will predispose the bones of these joints to stress fracture more likely [29,30]. However, whether which one of the limitations (heel rising and flatfoot condition) has more effect on patient poor performance is unclear and needs to further studies.

Limitation

One of the most limitations in our work was that we used a general musculoskeletal system. Although this limitation is important for interpreting our results, we had to use a general musculoskeletal model in the absence of other specific models which have enough validity, reliability, and acceptability for flatfoot patients. Also, some previous studies in this area investigated some tendon transfer of lower extremity muscles using a general musculoskeletal system in flatfoot patients [4, 17]. So, this limitation may not avoid from completing of our study with such models.

Conclusion

Assessments using a dynamic computer simulation can be used prior to surgery as the clinical tools to answer common questions. This study created a higher insight on how the FDL tendon transfer affects on foot performance and established a scientific basis to diagnose foot surgery side-effects. The dynamic computer simulation should be used as a clinical tool for consideration of pathological movements, foundation a scientific basis for treatment interventions, special treatment for certain patients, therapeutic expectations and predictions, and necessary treatment measures before surgery.

References

1. Hicks JL, Uchida TK, Seth A, Rajagopal A, Delp SL. Is my model good enough? Best practices for verification and validation of musculoskeletal models and simulations of movement. Journal of biomechanical engineering. 2015; **137**(2): 20-25.
2. Valente G, Crimi G, Vanella N, Schileo E, Taddei F. nmsBuilder: Freeware to create subject-specific musculoskeletal models for OpenSim. Computer Methods and Programs in Biomedicine. 2017; **1**(15):85-92.
3. Delp SL, Anderson FC, Arnold AS, Loan P, Habib A, John CT, Guendelman E, Thelen DG. OpenSim: open-source software to create and analyze dynamic simulations of movement. IEEE transactions on biomedical engineering. 2007; **54**(11): 40-50
4. Kapti AO. Dynamic simulation of tibialis posterior tendon transfer in the treatment of drop-foot. Biocybernetics and Biomedical Engineering. 2014; **1**(2):132-138.
5. Mansouri M, Clark AE, Seth A, Reinbolt JA. Rectus femoris transfer surgery affects balance recovery in children with cerebral palsy: A computer simulation study. Gait & posture. 2016; **31**(43):24-30.
6. Reinbolt JA, Seth A, Delp SL. Simulation of human movement: applications using OpenSim. Procedia IUTAM. 2011; **1** (2):186-198.
7. Maskill JT, Pomeroy GC. Flexor digitorum longus tendon transfer and modified kidner technique in posterior tibial tendon dysfunction. Clinics in podiatric medicine and surgery. 2016; **133**(1):15-20.

8. Vaudreuil NJ, Ledoux WR, Roush GC, Whittaker EC, Sangeorzan BJ. Comparison of transfer sites for flexor digitorum longus in a cadaveric adult acquired flatfoot model. Journal of Orthopaedic Research. 2014; **32**(1):102-109.
9. Johnson, K., & Strom, D. Tibialis posterior tendon dysfunction. Clinical Orthopedics and Related Research. 1989; **239**, 196–206.
10. Wacker JT, Hennessy MS, Saxby TS. Calcaneal osteotomy and transfer of the tendon of flexor digitorum longus for stage-II dysfunction of tibialis posterior three-to five-year results. Journal of Bone & Joint Surgery, British Volume. 2002; **84**(1):54-8.
11. Arnold AS, Liu M, Ounpuu S, Swartz M, Delp SL. The role of estimating hamstrings lengths and velocities in planning treatments for crouch gait. Gait and Posture. 2006; **23**(3):273-81.
12. Fox MD, Reinbolt JA, Õunpuu S, Delp SL. Mechanisms of improved knee flexion after rectus femoris transfer surgery. Journal of biomechanics. 2009; **42**(5):614-9.
13. Kreulen M, Smeulders MJ. Assessment of Flexor carpi ulnaris function for tendon transfer surgery. Journal of biomechanics. 2008; **41**(10):21-25.
14. Reinbolt JA, Fox MD, Schwartz MH, Delp SL. Predicting outcomes of rectus femoris transfer surgery. Gait & posture. 2009; **30**(1):100-105.
15. Seth A, Sherman M, Reinbolt JA, Delp SL. OpenSim: a musculoskeletal modeling and simulation framework for in silico investigations and exchange. Procedia Iutam. 2011; **1**(2):212-232.
16. Sherman MA, Seth A, Delp SL. Simbody: multibody dynamics for biomedical research. Procedia Iutam. 2011; **1**(2):241-261.
17. Chand, T. J., Ajay, S., Michael, H. S., & Scott, L. D. Contributions of muscles to mediolateral ground reaction force over a range of walking speeds. Journal of biomechanics. 2011; **45**(24):38-43.
18. Oatis CA. Kinesiology: the mechanics and pathomechanics of human movement. Lippincott Williams & Wilkins; 2009.
19. Neumann DA. Kinesiology of the Musculoskeletal System-E-Book: Foundations for Rehabilitation. Elsevier Health Sciences; 2013.
20. Hamill J, Knutzen KM. Biomechanical basis of human movement. Lippincott Williams & Wilkins; 2006.
21. Bojsen-Moller, F., & Lamoreux, L. Significance of free dorsiflexion of the toes in walking. Acta Orthopaedica Scandinavica. 1979; **50**(4): 471-479.
22. Laroche D, Pozzo T, Ornetti P, Tavernier C, Maillefert JF. Effects of loss of metatarsophalangeal joint mobility on gait in rheumatoid arthritis patients. Rheumatology. 2005; **45**(4):435-40.
23. Leardini A, Benedetti MG, Berti L, Bettinelli D, Nativo R, Giannini S. Rear-foot, mid-foot and fore-foot motion during the stance phase of gait. Gait & posture. 2007; **25**(3):453-62.
24. Myerson MS, Badekas A, Schon LC. Treatment of stage II posterior tibial tendon deficiency with flexor digitorum longus tendon transfer and calcaneal osteotomy. Foot & Ankle International. 2004; **25**(7):445-50.
25. Vora AM, Tien TR, Parks BG, Schon LC. Correction of moderate and severe acquired flexible flatfoot with medializing calcaneal osteotomy and flexor digitorum longus transfer. JBJS. 2006; **88**(8): 26-34.
26. Wacker JT, Hennessy MS, Saxby TS. Calcaneal osteotomy and transfer of the tendon of flexor digitorum longus for stage-II dysfunction of tibialis posterior three-to five-year results. Journal of Bone & Joint Surgery, British Volume. 2002; **84**(1):54-58.
27. Winter DA. Biomechanics and motor control of human gait: normal, elderly and pathological. 1991.
28. Erdemir A, Hamel AJ, Fauth AR, Piazza SJ, Sharkey NA. Dynamic loading of the plantar aponeurosis in walking. JBJS. 2004; **86**(3):546-552.
29. Queen RM, Abbey AN, Chuckpaiwong B, Nunley JA. Plantar loading comparisons between women with a history of second metatarsal stress fractures and normal controls. The American journal of sports medicine. 2009; **37**(2):390-395.

30. Weist R, Eils E, Rosenbaum D. The influence of muscle fatigue on electromyogram and plantar pressure patterns as an explanation for the incidence of metatarsal stress fractures. The American journal of sports medicine. 2004; **32**(8):93-98.

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چکیده فارسی

شبیه‌سازی دینامیکی انتقال تاندون عضلهٔ خم کنندهٔ طویل انشگتان پا برای درمان افراد دارای کف پای صاف

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ناکارآمدی عضله درشت نئی خلفی منجر به ناهنجاری کف پای صاف اکتسابی در بزرگسالان می‌شود. ناکارآمدی عضله درشت نئی خلفی معمولاً با انتقال تاندون فلکسور طویل انگشتان به برجستگی استخوان ناوی درمان می‌شود. در سال‌های اخیر از مدل‌سازی پویای رایانه‌ای جهت پیش‌بینی نتایج درمان و جراحی مورداستفاده قرارگرفته است. هدف این مطالعه ارائه مدل پویای رایانه‌ای انتقال تاندون فلکسور طویل انگشتان برای پیش‌بینی درمان کف پای صاف بود. در این مطالعه از مدل مفصل مچ پای ۳ بعدی که متشکل از ۲۹ استخوان و ۱۱ عضله که توسط نرم‌افزار OpenSim تولیدشده بود استفاده گردید. با استفاده از نرم‌افزار نمودار گشتاور فلکسوری مفاصل مچ پا، کف‌پایی- انگشتی و گشتاور اینورتوری مفصل ساب تالار رسم شد. بعد از انتقال تاندون فلکسور طویل انگشتان گشتاور پلانتار فلکسوری مچ پا ۶/۷ درصد و گشتاور پلانتار فلکسوری مفصل کف‌پایی- انگشتی ۴۵ درصد کاهش نشان داد. همچنین گشتاور اینورتوری مفصل ساب تالار با کاهش ۳۴ درصدی مواجه شد.

کاهش گشتاور پلانتار فلکسوری باعث تغییر قابل‌توجهی در مفصل مچ پا نشد اما در مفصل کف-پایی انگشتی می‌تواند باعث محدودیت در بلند شدن پاشنه در مرحله پیشروی راه رفتن و یا دویدن شود. کاهش گشتاور اینورتوری مفصل ساب تالار می‌تواند بیومکانیک اندام تحتانی را دچار اختلال کند.

واژه های کلیدی: انتقال تاندون فلکسور طویل انگشتان، کف پای صاف، مدل‌سازی، اوپن سیم

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