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GAIT JOINT FORCE BEHAVIOR IN TOTAL ANKLE REPLACEMENT AT MEDIUM TERM

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INTRODUCTION

Decreased survival at tenth year [1], significantly more functionality at medium term (between one and six years) [2,3] and Increased risk of revision [1] in subjects with posttraumatic total ankle replacement (TAR) versus other etiologies has been described. Since 1970 more than thirty designs were introduced to lower outcomes respect hip and knee arthroplasty [1,4] linked to the development force during stance phase of gait [4]. Change in magnitude and/or distribution during functional activities have show compromising survival, wear and integrity of bone-implant of the TAR [2,5,6]. Nevertheless, knowledge about in vivo ankle joint force behavior (AJFB) with unilateral Hintegra TAR during gait in functional status is uncertain [6]. Based on this, the present study aims describe the ankle joint force behavior and yours mechanical conditioning during in vivo gait analysis in subjects with unilateral posttraumatic Hintegra TAR at medium term.

METHODS

Eight subjects were implanted with the Hintegra prosthesis (Newdeal SA, Vienne, France) and received the same guide of physical therapy [2] for the foot and ankle service (Trauma Institute, Santiago, Chile). Subsequently, the TAR group and the control group (Table 1) were made up three-dimensional analysis (CEMH, Santiago, Chile). Subjects walked barefoot on two force platform (AMTI, Watertown, MA) at self-selected speed according to the Helen Hayes protocol [7] captured by eight Hawk synchronized cameras (Motion Analysis Co., Santa Rosa, CA).

Discrete and continue values of the AJFB (compressive, anteroposterior, mediolateral joint force and shear force direction) and discrete values of mechanical conditioning (external vertical force, ankle joint moment and active ankle sagittal range of motion) was measured. The kinematic signal was acquired at 50 Hz and filtered with a second order low pass butterworth filter through Cortex 1.3.0.562 software (Motion Analysis Co., Santa Rosa, CA). The kinetic signal was acquired at 100 Hz by extracting to the Orthotrak 6.5.1 software (Motion Analysis Co., Santa Rosa, CA) using the inverse dynamic method.

Cross correlation analysis [8] using Igor pro 6.02 software (Wave Metric inc., Lake Oswego, OR) was made regarding group means [9]. Statistical analysis using Stata 12.0 software (Stata Corp LP, College Station, TX) was used to apply the Shapiro-Wilk test ($p<0.05$) obtaining a non normal distribution and the U Mann-Whitney test unpaired ($p<0.05$) to discrete values of both groups.

Table 1. Subjects characteristic.

	TAR Group	Control Group
Age (years)	54.5±12.0	55.1±3.6
Height (m)	1.57±0.06	1.59±0.06
Mass (Kg)	74.1±2.6*	62.7±11.7
AOFAS (pnts.)	55.6±22.6*	99.4±1.0
SPRoM (°)	27.7±4.7*	75.6±11.2
Ev. Time (month)	43.5±12.7	-

SPRoM= Passive ankle sagittal range of motion. Ev. Time= Post surgery evolution time. AOFAS= The American Orthopaedic Foot and Ankle Society score. *= Statistical difference.

RESULTS AND DISCUSSION

The discrete values of AJFB and mechanical conditioning are summarized in Table 2 and Table 3. The mayor continues alterations of AJFB are summarized in Figure 1.

Table 2. Discrete Values (peaks) of AJFB.

	TAR Group	Control Group
Compressive JF		
1st C. Peak (WB)	0.98±0.20	1.08±0.10
2nd Peak (WB)	0.96±0.11*	1.15±0.15
Anteroposterior JF		
Post. Peak (WB)	-0.05±0.02*	-0.20±0.10
1st Ant. Peak (WB)	0.06±0.03*	0.25±0.03
2nd Ant. Peak (WB)	0.11±0.10*	0.33±0.20
Mediolateral JF		
1st Lat. Peak (WB)	0.10±0.10	0.13±0.13
2st Lat. Peak (WB)	0.17±0.16	0.21±0.21

JF= Joint Force. *= Statistical difference.

The significantly lower posterior peak (Post. Peak), the moderate anteroposterior asymmetry during the loading response and significantly higher firs peak time (1st Peak t) in TAR group suggest the presence of a delayed loading response [11] during the development of the "shock absorbing mechanism" [12]. Nolan et al. (2011) describes that a delay in transfer efficiency of the Center of Mass (CoM) alters the loading response by first rocker dysfunction in patients with hemiparesis [13]. McCrory et al. (2001) in subjects with unilateral hip arthroplasty suggests an adopted antalgic pattern associated with osteoarthritis [14] like Horisberger et al. (2009) & Valderrabano et al. (2007) describes in subjects with unilateral posttraumatic ankle osteoarthritis [3,15].

Table 3. Mechanical Conditioning Values.

	TAR Group	**Control Group**
Vertical Force		
1st Peak (WB)	1.03±0.21	1.15±0.20
2nd Peak (WB)	1.00±0.14	1.28±0.39
1st Peak t (%)	34.0±6.0*	31.0±4.9
2nd Peak t (%)	71.0±5.0*	80.8±4.5
ASRoM	10.8±3.7	17.4±7.7
Ankle Joint Mom.		
DF Peak (WBm)	-0.03±0.03	-0.22±0.04
PF Peak (WBm)	1.06±0.25*	1.53±0.09

ASRoM= Active ankle sagittal range of motion. Peak t= time in external vertical force development. *= Statistical difference.

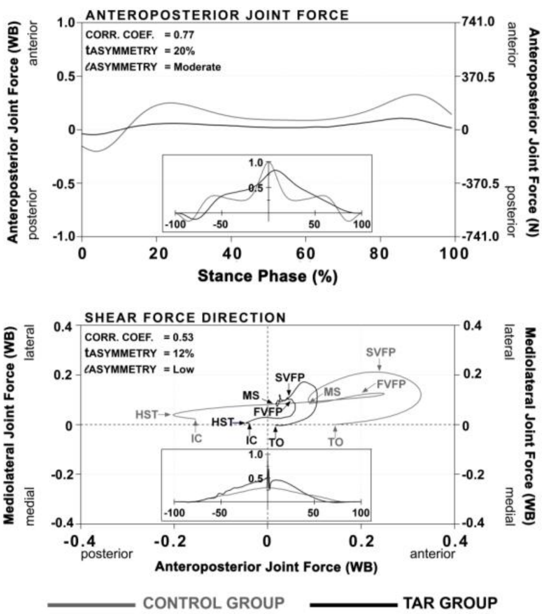

Figure 1: Ankle Joint Force Behavior. IC= Initial Contact. HST= Heel Strike Transient. FVFP= First Vertical Force Peak. MS= Mid Stance. SVFP= Second Vertical Force Peak. TO= Toe off. Cross Correlation Analysis in box. CORR. COEF.= Cross correlation coefficient. tASYMMETRY= moment of maximal difference between autocorrelation signal of control group (in black line into the box) and Tar-control group cross correlation signal (in grey into the box). ℓASYMMETRY= maximal difference between autocorrelation signal of control group (in black line into the box) and Tar-control group cross correlation signal (in grey into the box).

The significant minor second compressive peak (2nd C. Peak), the significant minor first (1st Ant. Peak) and second (2nd Ant. Peak) anterior peak, the significant minor platarflexion peak moment (PF Peak) and significant minor second peak time (2nd Peak t) in TAR group, suggest the presence of an insufficient push off by inefficient "plantar flexion knee couple" [7]. Consistent with the findings of Ingrosso et al. (2009) & Valderrabano et al. (2007) in subjects with posttraumatic unilateral TAR, significantly minor plantarflexion moment after twelve months post surgery is an indicator of impaired propulsion ability by triceps surae inefficiency, factor noted in energy regulation for anterior acceleration of CoM [16]. The inefficient "plantar flexion knee couple" develops a secondary lateral rotation relative to the line of foot progression decreasing the mechanical efficiency in a sagittal ankle plane [12] requiring early CoM transfer shortening the terminal double support [7]. That suggests a compensated hip action and findings about more extensors and lateral hip rotators activations found by Ingrosso et al. (2009) and Knarr et al. (2012) in subjects with unilateral TAR and plantar impairment respectively, imply that strategy [2,17].

The less excursion of shearing vector components (Figure 1) in TAR group thought the Hintegra TAR is non constrain, fosters a central compressive component generating repetitive load on interface and tibial trabecular. This behavior probably has a greater contribution of intrinsic coronal prosthetic stability, ankle hipomobility, possible abnormal coactivation [15] as the development of a protective joint strategy with decreased ankle peaks moments incorporates in the end stage of posttraumatic ankle osteoarthritis to reduce ankle joint loading and joint shear force [3].

CONCLUSIONS

The main findings of our study were an abnormal compressive and shear joint force behavior, predominantly in the anteroposterior plane with abnormal mechanical conditioning during damping and propulsion function in subjects with posttraumatic unilateral TAR at medium term. This suggests that a delayed loading response and inefficient push off develop an inappropriate local loading shear environment, predisposing to increased wear of the central portions of the prosthesis interface.

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