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A PARTIAL FUNCTIONAL RESTORATION AFTER HALLUX VALGUS CORRECT SURGERY - A CONTROLLED PRELIMINARY STUDY

[1]Jean-Philippe Siracuse
[*1,2]Florian Forelli
[1]Jean Mazeas
[3]Jérôme Sadaka
[3]Rémy Touzard
[3]Matthieu Trousselier
[1,2]Maude Traullé

ABSTRACT

Introduction: Hallux valgus is the most common condition found in the foot, caused by a progressive failure of the first ray stabilization means. The hallux is deviated into valgus, the first metatarsal into varus, and their association leads to a subluxation of the metatarsophalangeal joint of the first ray. Surgery is a treatment frequently used to correct this condition. So, is the static postural balance altered after corrective surgery?

Materials and Method: 23 subjects participated in the study, all women, divided into two groups: control and hallux valgus. The hallux valgus group was evaluated three months post-operatively. Bipodal tests were carried out on a stabilometry platform, one with eyes open and one with eyes closed. The pressure center parameters were recorded and analyzed, such as the length or the area of the pressure center.

Results: The results obtained showed significant differences between the two groups and were statistically significant, with a p-value of 0,05. The pressure center values are higher in the hallux valgus group.

Conclusion: Some results found in the literature agree with the results of the present study. There are significant deficits in the static postural balance three months after corrective surgery. Other studies with a larger sample may be performed to confirm or not the results of this study.

Keywords: hallux valgus, static postural balance, stabilometry, center of pressure.

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[1]Researcher Physical Therapist in OrthoLab, Clinic of Domont, France.
[3]Ankle and Foot Orthopaedic Surgeon, MD, Clinic of Domont, France.

CORRESPONDING AUTHOR

[*1,2]**Florian Forelli**

Researcher Physical Therapist in OrthoLab, Clinic of Domont, France.
Co-director OrthoLab, Clinic of Domont, France. e-Mail: fforelli@capio.fr

INTRODUCTION

Hallux valgus is the most frequently acquired forefoot disorder, with 26.3% of the prevalence of plantar diseases, according to *Hagedorn and al;* in 2013 [1]. The evolution over time shows an increasing incidence of HV according to age: 23% of people aged 18 to 65 against 35.7% over 65 according to the teams of *Carvalho and al* or *Nix and al* [2 –4]. This evaluation is supported by the study by *Abhishek and al* [5] who, in 2010, estimated the prevalence of HV at 28.4% in adults over 40 years of age. This acquired disorder presents a sex ratio of 15 women for 1 man, according to the *Piclet-Legré* work of 2017 [6].

This disorder develops according to several distinct pathophysiological patterns. It can be congenital, juvenile, or acquired, the prevalence of which is the highest. This form develops after adolescence and remains progressive throughout the life of the affected subjects. The present study focuses on this form of HV.

The pathophysiological mechanism is secondary to a progressive failure of the first ray stabilization means. This failure leads to an evolutionary deformation of the first ray combining bone, muscle, joint and capsular-ligament damage. The hallux has deviated into valgus with a pronation component, the first metatarsal (M1) is deviated into varus with, also, a pronation component. The head of M1 protrudes medially, forming an exostosis with thickening of the capsular fibrocartilage and where osteophytes can develop. This protrusion thus leads to a subluxation of the metatarsophalangeal joint of the first ray (MTP1) [7]. The HV, therefore, corresponds to a catch-up mechanism and causes the 1st phalanx in valgus at the risk of causing dislocation of the sesamoids in the inter-metatarsal space.

The deformation process is allowed thanks to an imbalance of the ligamentary forces, mainly concerning the medial part of the MTP1. Just like the muscular forces, including the long tendons specific to hallux, will tend to take the bowstring as explained by *Hecht and Lin* in 2014 or *Piclet-Legré* in 2017 [6,7].

This pathology leads to a dysfunction of the first ray resulting in an impairment of the function of the foot, as described by *Winter* in 1995 [8], by the difficulties of putting on and the pain caused. Thus, the standing position can be modified and lead to real postural disorders, according to *Sadra and al;* in 2013 [9].

Surgical correction of HV is a solution to this condition. The Scarf procedure has excellent efficiency in correcting the deformation acquired in HV in the three planes of space, as explained by *Smith and al; in* 2012 [10]. As a result, each subject operated on for HV in this study benefited from this intervention.

The objective of the surgical intervention is to restore the various functions that have been impaired, including the postural function. Balance is defined as the maintenance of the vertical projection of the center of mass (CoM) of the body on the support area formed by the feet. The center of gravity (CoG) is defined as the vertical projection of the CoM on the ground. The center of pressure (CoP) is the point of application of the reaction force on the ground under the impulse of body mass. In the context of stabilometry, the CoP is comparable to the CoG, with an error of almost 1%, according to *Gagey and Web*er in 2005 [11].

The posture describes the position of the different body segments with each other but also in space. The stabilometry platform measures the position of the CoP, expressed in a two-dimensional frame of reference whose plane coincides with that of the support polygon and whose origin of its coordinates is located at the barycentre of the same polygon [11]. It then appears that stabilometry is an effective way to quantify and assess the postural consequences of corrective surgery on hallux valgus operated patients.

In this context, the objective of this study is to analyze the variation in the movement of the pressure center in patients operated on for three months with an HV using a stabilometry platform and to compare it with the variation CP movement of a healthy population and to analyze the static postural balance by plantar pressures in these same patients with the same platform and compare it to a healthy population.

The hypothesis put forward is that after surgery, the analysis of the parameters of CoP in subjects with HV is similar to that in healthy subjects. To answer this question, the work presented corresponds to a preliminary study, the objective of which is also to observe the feasibility of the protocol as well as the consistency of the results obtained compared to the literature.

MATERIALS AND METHOD

Population

To answer this research question, patients undergoing corrective hallux valgus surgery were recruited to a French clinic by two experienced orthopedic surgeons. We were able to recruit 23 volunteer subjects, all women, divided into two groups: an asymptomatological control group (CG), consisting of 11 subjects between 20 and 65 years of age and a group of operated subjects (HVG), consisting of 12 subjects in the same age group. All subjects in the test group were operated on for HV using the Scarf technique three months ± one month before the tests were carried out.

The inclusion criteria are for the CG, being between 20 and 65 years old, bipodal static test possible. For HVG, subjects must be between 20 and 65 years old and acquired hallux valgus, have been operated on for three months ± one month, and be able to carry out a bipodal static test with eyes open and eyes closed for 51.20 seconds [9].

The non-inclusion criteria are, for the CG, to have suffered a trauma to the lower limb in the last six months, to have had a fall during the previous six months, to take medical treatment which could affect balance or to practice a high-level sport. For HVG, these non-inclusion criteria are to have benefited from another operating technique than Scarf (Chevron, Lapidus, etc.), to have a congenital or juvenile hallux valgus, to suffer from a metabolic, neurological pathology, to suffer from severe impairment of the visual, vestibular, proprioceptive, auditory system or even taking medication that may affect balance. Failure to perform clinical tests is an exclusion criterion.

Materials

The data was acquired with the following equipment: a Fusyo medicapteur® stabilometry platform (54x60cm), a computer (DELL®, 256GB SSD, 1.00 TB hard drive, intel core® i7 processor, 8.00GB RAM, Windows 10®), a USB 2.0 cable, connecting the platform to the computer's central unit, the Fusyo® software (V8.4 MC, TwinBox V7.80, FUSYO2).

Protocol

As a preamble to the measurements, the parameters age, weight, height, date of birth, pathology, and laterality of the operated foot were entered in the software. The 2Mes - OF - 40 Hz test was used; it consists of two successive measurements at 40 Hz or 2048 values per measurement. The subjects were installed on the platform with stakes as follows: bare feet on the platform, feet in contact with the stakes, feet apart and forming an angle of 30 °, spaced 2 cm apart and position of the lower limb knee stretched according to AFP 85 [11] standardized standards. Once the subject was installed correctly, the tutors were removed, and the tests could be carried out.

The first test is performed with open eyes (EO), subject standing in bipodal support, standardized foot placement, upper limbs aligned with the length of the trunk, for 51.20 seconds. A closed eye test (EC), carried out in the same position as the previous one, follows it [2,4,9,12,13]. For the EO test, the patient was asked to look at the marker (dots of different colors depending on the height of his gaze so that it is horizontal), located at a distance of 2 meters in front of him [2]. The EC test was carried out with a short break after the EO test under the same conditions, by launching it with the subject's agreement.

During the acquisitions of the tests, EO as EC, no sound, or visual stimuli was accepted. The examiner was placed behind the subject to ensure his safety and so as not to enter his field of vision. The tests were acquired only once; no patient needed to start again. The data acquisition took place between November 2018 and April 2019. The duration of the data acquisition sessions was 15 minutes (± 5 minutes) per subject.

Statistical analysis

The data analyzed are the most commonly studied in stabilometry, it is the displacement of the pressure center according to the following parameters: Xmoy (mean position of the CoP along the X-axis), Ymoy (mean position of the CoP along the axis of Y), length (total distance traveled by the CoP), 95% area of CoP displacement and Vmoy (average speed of the CoP).

Comparisons between groups were made using the Mann-Whitney test. The statistical significance threshold was set at $\rho < 0.05$. Statistical analyses were performed with R® software (R Development Core Team 2011, Bell Laboratories, Murray Hill, NJ, USA).

RESULTS

After the homogeneity test carried out using the Mann-Whitney test, the results of which are visible in Table 1, it turns out that the GC and the GHV did not show any significant difference for the size, weight, and Body Mass Index (BMI). However, a significant difference appeared for the age characteristic.

Table 1: Inter-group comparison of demographic characteristics

	GC (n=11) AVE ± SD	GHV (n=12) AVE ± SD	ρ-value
Age (y)	35,09 ± 11,79	47,75 ± 10,27	**0,026***
Size (m)	1,63 ± 0,05	1,64 ± 0,06	0,401
Weight (kg)	63,18 ± 13,34	69,54 ± 20,15	0,325
BMI (kg/m²)	23,63 ± 4,72	25,72 ± 7,24	0,601

AVE = average; SD = Standard Deviation; y = years; m = metre; kg = kilogram; kg/m² = kilogram per square metre; n = number of subjects

* = significant difference

With open eyes, the raw results of which are detailed in Table 2, a significant difference appears between the GC and GHV for the characteristics Ymoy, Vmoy, and length. Indeed, the values of these parameters are more important for the GHV (Vmoy and length), and the Ymoy is significantly distinct. However, the GC and the GHV do not show any significant difference for the Xmoy and surface characteristics.

Table 2: Intergroup comparison of the characteristics of the pressure center for the bipodal open eye test

	GC (n=11) AVE ± SD	GHV (n=12) AVE ± SD	ρ-value
Xmoy (mm)	6,86 ± 12,79	-2,25 ± 18,63	0,104
Ymoy (mm)	-56,42 ± 22,30	-32,8 ± 28,48	**0,027***
Length (mm)	550,48 ± 208,11	940,76 ± 595,61	**0,037***
Area (mm²)	193,24 ± 97,29	196,66 ± 62,34	0,487
Vmoy (mm/s)	10,89 ± 4,09	18,37 ± 11,62	**0,044***

AVE = average; SD = Standard Deviation; mm = millimetre; mm² = square millimetre; mm/s = millimetre per second

* = significant difference

With eyes closed, the raw results of which are detailed in Table 3, a significant difference appears between the GC and GHV for the characteristics Ymoy, length, surface, and Vmoy. Indeed, the values of these parameters are more important for the GHV (Vmoy, surface, and length), and the Ymoy is significantly distinct. However, GC and GHV do not show a significant difference for the parameter Xmoy.

Table 3: Inter-group comparison of the characteristics of the pressure center for the bipodal closed eyes test

	GC (n=11) AVE ± SD	GHV (n=12) AVE ± SD	ρ-value
Xmoy (mm)	8,42 ± 11,92	-2,13 ± 21,43	0,091
Ymoy (mm)	-51,79 ± 22,43	-29,26 ± 29,08	**0,049***
Length (mm)	633,4 ± 140,79	1123,39 ± 500,36	**0,004***
Area (mm^2)	140,83 ± 53,20	251,69 ± 100,22	**0,004***
Vmoy (mm/s)	12,29 ± 2,75	21,95 ± 9,77	**0,006***

AVE = average; SD = Standard Deviation; mm = millimetre; mm^2 = square millimetre; mm/s = millimetre per second

* = significant difference

DISCUSSION

Results analysis

Concerning demography, the parameters size (ρ = 0.401), weight (ρ = 0.325) and BMI (ρ = 0.601) an inter-group homogeneity. However, for the age parameter (ρ = 0.026), the distribution is not normal and shows an inter-group heterogeneity. As a result, the results obtained are not necessarily to be excluded but to be interpreted with restraint: age having an influence in postural control as well as in the function of the foot [14], it is difficult to make a proven decision on the conclusions of this study.

The analysis of the CoP shows that at the level of the bipodal tests, EO as EC, several significant differences are found. This suggests that despite the surgery, HVG does not have a static balance similar to CG.

The Xmoy parameter does not show statistically significant differences between the two groups, both for the EO test (ρ = 0.104) and for the EC test (ρ = 0.091). However, the parameter Ymoy shows a statistically significant difference between the two groups, whether it is the EO (ρ = 0.027) as the EC (ρ = 0.049). The position of the CoP for HVG is earlier than that of the control subjects, whatever the test. This parameter reflecting the use of the anteroposterior muscle chains, stabilization in the sagittal plane is impaired for HVG. The work of *Sadra and al* in 2013 [9] shows similar results with a significant difference in postural balance in the sagittal plane but no difference in the frontal plane. However, the parameter evaluated is CoM, which is independent of the CoP. The convergence of these results should be put into perspective.

The parameters Length, Area, Vmoy and the Romberg Quotient (RQ) are not treated in the literature in a way comparable to the protocol of this study. These parameters make it possible to envisage the energy expenditure during the bipodal tests but also the stability of the subjects, EO, as EC. The Length and the Vmoy show statistically significant differences between the groups. These parameters show that the estimate of energy expenditure is at least 68% higher EO and at least 70% higher EC for HVG compared to CG.

About the area, the EO test only shows a difference of 1.77% between the two groups, but it is significant. During the EC test, this difference goes to 78.8% (ρ = 0.004), which suggests that this parameter is dependent on the visual factor. The RQ makes it possible to decide on the impact of vision during the tests. Indeed, the RQ of HVG is 65.49% higher than that of CG. The HVG RQ being 136.93%, the impact of sight promotes postural balance for this group. This information suggests a potential proprioceptive deficit three months from such an intervention.

Specific parameters of static postural balance are significantly altered in HVG compared to CG, and this alteration is increased deleteriously during EC bipodal tests. The literature indicates that subjects with a deformity in HV appear to have an impairment in overall postural balance. Indeed, the work of *Nix and al* of 2012, those of *Hagedorn and al* in 2013 and those of *Hurn and al* in 2015 [1,4,15] show a significant difference in the mediolateral swing in bipodal position between a healthy population and subjects suffering from HV without showing any difference in the sagittal plane. However, the study of *Hurn and al* [15] approaches it. Three months after corrective intervention for the deformity in HV, using the Scarf technique, the posture does not seem to be restored.

Limits and outlook

Analysis of the sample showed a statistically significant difference in the age parameter. This value alters the interpretation and comparison of the two groups. The respective studies of *Carvalho and al;* and *Scott and al* in 2007 [2,14] have shown that advancing age leads to a decrease in foot function.

Analysis of the protocol shows a bias in the number of tests carried out for the tests. Different studies agree that between 2 and 5 trials are recommended to have a reliable data record [16,17]. However, it is necessary to pay attention to the learning effect due to repeated tests, which could tend towards a decrease in postural sway. Regarding the duration of each trial, the literature reports various opinions and advice [2,16–18]. Besides, too short an acquisition period would not allow the postural control mechanism to be precisely distinguished. Conversely, too long an acquisition period would cause the subject to experience fatigue or reduced attention, which would alter the quality of the acquisition.

Based on these observations, a future study aimed at supplementing this should be made up of at least three trials to have a better representation of the capacities of a given population. It would be beneficial to add a break between each acquisition to avoid the effect of fatigue due to the number of tries. Furthermore, being only a preliminary study here, it would be a question in the future of increasing the number of subjects while homogenizing the age of these, which would allow a better interpretation of the results.

CONCLUSION

The posture seems to be disturbed three months after corrective surgery for hallux valgus with a dependence on the visual factor; however, there is nothing to identify the source of this disturbance specifically. The literature does not provide an answer today but suggests that the deformation causes postural disorders. Thus, three months after correcting it, the postural disturbances could persist and require specific treatment.

This study corresponds to a preliminary work and will be followed by a larger trial to increase the power of the results. It would be advisable to take measurements before the surgical intervention, to be able to objectively attribute the disorders to the deformation or the postoperative operations, in which case, the postoperative delay of the measurements could be reviewed.

ALL THE ABBREVIATIONS

Hallux Valgus	HV
First metatarsal	M1
Metatarsophalangeal joint of the 1st column	MTP1
Centre of Gravity	CoG
Centre of Mass	CoM
Centre of Pressure	CoP
Control group	CG
Hallux Valgus operated group	HVG
Eyes open	EO
Eyes close	EC
Romberg quotient	RQ
Average position of the CoP along the X axis	Xmoy
Average position of the CoP along the Y axis	Ymoy
Average speed of the CoP	Vmoy
Body Mass Index	BMI

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