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**Original Article**

# Balance and posture: effects of proprioceptive training on a group of sedentary people

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**Abstract**
*Objectives:* The object of this study was to evaluate the effects of proprioceptive exercises on the parameters associated with stability and posture and how these changes following the stress offered by a proprioceptive insole, placed under the plantar surface during the evaluation tests in pre (T0) and post- training (T1). *Data sources:* Participants was 19 sedentary subjects (aged 31.4±3.6) divided in experimental group (EG = 4 males and 6 females) and control group (CG = 3 males and 6 females). The first (EG) performed a proprioceptive training for the system podalic; the second (CG) performed only postural exercises. The training was done daily by the subjects, for a duration of 10 weeks. The stabilometric parameters taken into consideration for our study were: Xmoyen/Ymoyen, Surface, VarVit, AVG/TALG, AVD/TALD, IVV, ROMBERG as they are variables that allow an immediate interpretation of a person's stability. *Results:* The t-test in the experimental group (open eyes) with the insole, showed statistical significance in the VarVit parameter (p =.03 - r =.94); with eyes closed, the significance was found in the parameter surface (p =.01 - r =.7) with a further reduction of the variation in velocity/VarVit (p =.07 - r =.6). The control group significantly improved the speed-variance/VarVit in closed-eyes at dynamic mode (p=.04 - r =.06). *Main results:* The results of this study indicate that "stresses" provided represent a type of activity capable of effectively activating the proprioceptive control aimed at reducing disequilibrium. *Conclusions:* The results of this study show that the solicitations provided through proprioceptive training represent a type of activity capable of effectively activating proprioceptive control with the aim of reducing the imbalance.
**Key words: postural stability, stabilometric evaluation, proprioceptive exercises**

## Introduction

The neuroscience study has changed the posture concept, moving from a biomechanical reductionist concept to a cybernetic model, consisting of inputs, elaborations, control of reactive functions (reflexes) through feedback and feedforward circuits.

Unlimited simple and complex postures have thus been realized, which can be understood through the Fine Postural System (FPS) or Global Postural System (GPS) activity. There is a *"dialogue"* constantly in progress between various structures and systems which is aimed at maintaining posture itself. Controlling posture is a complex task, and proprioception plays a crucial role. The continuous oscillations or the state changes are necessary to produce the action potential in the proprioceptive receptors; the frequencies generated through these potentials inform the FPS. The FPS manages the best response in the prefrontal cortex for the orthostatic condition realization based on genetic evolution and in opposition to the gravity force and life experience (Sirousi, Akbari, Teymuri & Akbari, 2018; Mouchnino, Lhomond, Morant & Chavet, 2017).

We perceive in view of movement, but we need to move in order to perceive (Nart & Scarpa, 2008). Supervising these changes and the adaptation of posture are the task of the Tonic Postural System (TPS) with, at the upper level, the orientation system (Carini et al, 2017), which governs the eyes, and, at the lower level, the adaptive system, which governs feet. The proprioceptive sensitivity of plant pressure allows organizing an optimal kinesthetic response and, combined with the other sensory inputs, optimizes postural strategies (Teasdale et al, 2017; Mochizuki & Amadio, 2003).

An important role is played by the relationship between oculomotor muscles and plantar touch, the main proprioceptive receptors of the Tonic Postural System that regulate the visuo-podalic axis and the relationship between the orientative and adaptive part of the body is integrated by the oculocephalogyria pathways (Rossato & Rossato 2020; Roll, Roll & Kavounoudias, 2002). Educating the proprioceptive reflexes in the person's performance could be a valid strategy to improve stability and balance ability (Lucchetti, Biancalana & Rossato, 2019; Nart & Biancalana, 2013; Horak, 2006).

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***The foot in a postural perspective.***

The foot is the base of the ascending muscle chain and, together with the ankle, absorbs and adapts to postural problems. It is a fundamental receptor of the system: all the vectors generated by the body movement act on it in order to re-establish balance and stability. The balance disorders perceived by the feet modify the muscular tonic activity that intervenes to protect the system (Scheibel, Zamfirescu, Gagey & Villeneuve, 2017). The tibiotarsal joint is the pivot of the "inverse pendulum" that divides the plant pressure with the rest of the body which coincides with the oscillating mass (Paillard, 2017; Gagey & Webwer, 2000).

Foot pressure affects the position and functioning of the rest of body segments; it is a receptor perpetually in contact with the ground and, consequently, it undergoes the modifications of the latter (Kennedy & Inglis, 2002). The foot structure allows the muscle receptors, the receptors located in the joints and the mechanoreceptors located under the skin to simultaneously provide a response to the same stimulus, which must have its own intensity, frequency and duration and reach the threshold value. The skin, muscular and articular receptors of the foot inform the system on balance and posture.

***Proprioceptive insole.***

The purpose of the proprioceptive insole is to trigger *correction reflexes* influencing muscular proprioception in the feet with an immediate response on stability and equilibrium parameters (Strzalkowski, Mildren & Bent, 2015) highlighting variations in the lateral position of the pressure centre, in the pressure surface and in the anteroposterior oscillations (Rajachandrakumar, Mann, Schinkel-Ivy & Mansfield, 2018).

The necessity of measuring in an objective and statistically valid manner led to the choice of a stabilometry, a modern and sophisticated measuring instrument used as an evaluation tool.

The stabilometry measures the balance or imbalance of the human body, through some parameters that measure the footprint changes over time, both in static and in dynamic mode. Some stabilometric parameters can be improved with the willpower and exercise. In the project participants (sedentary subjects) the effects of proprioceptive exercises for the proprioceptive foot-ankle couple were observed (Maitre & Paillard, 2016).
It was also observed how the stability parameters vary following the solicitation of a proprioceptive insole placed under the plantar surface in the course of the benchmark tests.

## Material & methods

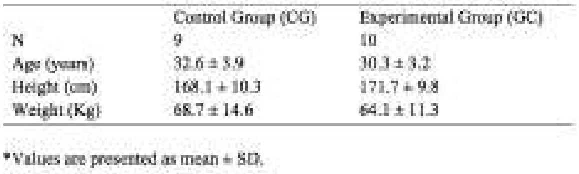
### Participants

The project involved 19 subjects divided in two groups randomly: **CG** control group (3 males and 6 females), **EG** experimental group (4 males and 6 females). The participants, chosen on the basis of inclusion and exclusion criteria, voluntarily joined and signed the related informed consent.

The inclusion criteria were as follows: persons aged between 25 and 40 years old, in a state of health, sedentary and not involved in work activities, free from inflammatory or degenerative diseases of the Central Nervous System and from congenital plant pressure malformations.

The participants characteristics shown in Table 1.

**Table 1:** Participants characteristics at baseline testing*.



| | Control Group (CG) | Experimental Group (GC) |
|---|---|---|
| N | 9 | 10 |
| Age (years) | 32.6 ± 3.9 | 30.3 ± 3.2 |
| Height (cm) | 168.1 ± 10.3 | 171.7 ± 9.8 |
| Weight (Kg) | 68.7 ± 14.6 | 64.1 ± 11.3 |

*Values are presented as mean ± SD.

### Procedure

The participants (EG-CG) underwent stabilometric assessment at basal time (T0) and after 12 weeks of training (T1). The EG protocol involved training based on proprioceptive exercises (gaits on the heels, on the toes, on the inner and outer sides of the foot, rolling forward and backward) associated with exercises on the horizontally pivoted platform to be performed for 30 minutes a day, with the aim of stimulating specific receptors while allowing a foot postural reprogramming (Quinlan, Yan, Sinclair & Hunt, 2020; Lesinki et al, 2015; Zech et al, 2010).

Postural training exercises for general mobilization (excluding podalic exercises) for a total duration of 30 minutes per day was proposed to the CG group. Assessments were carried out in six different ways, namely: static with open eyes; static with closed eyes; dynamic with open eyes; dynamic with closed eyes; dynamic with open eyes with proprioceptive insole; dynamic with closed eyes with proprioceptive insole.
The procedure seems in Figure 1.

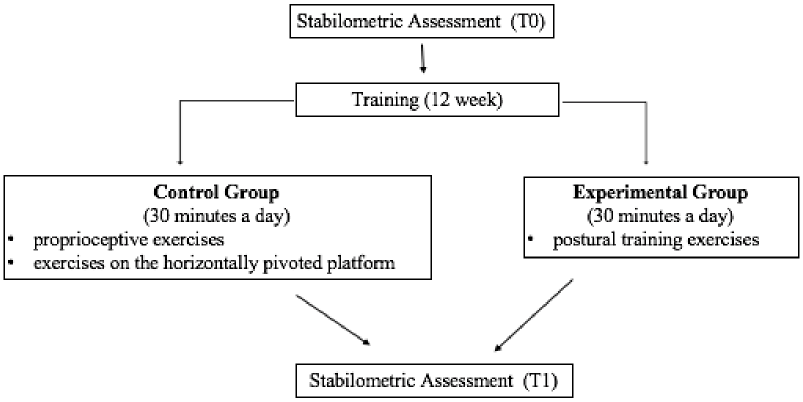


**Figure 1:** Research design of the experimental protocol.

All subjects involved underwent the following tests:

***- Assessment of the scapular plane with the SprintWARE Medical programme***

The program allows objectifying the morphological assessment of the subject on the anterior/posterior frontal plane and on the right/left sagittal plane, according to Barré's vertical; if seen sideways, it may show an imbalance of the anterior or posterior posture with respect to Barré's vertical (Gagey & Weber, 2000).

The sagittal plane test showed the presence in the sample of an anterior scapular plane; the use of a proprioceptive insole under the feet with symmetrical lateral reliefs was therefore proposed for the stabilometric assessment in dynamic mode.

***- Stabilometric assessment***

- *Cyber Sabots TM* stabilometry was used in static mode (eyes open / closed - OE / CE) for evaluating the effects of proprioceptive training; the data were processed using the *SabotSoftwareVib* software.

- *Positioning template* to insert the Sabots and evaluate the subject in orthostatic position with the feet at 30° and a 2 cm distance between the heels, or with parallel feet.

- *Bessou's platform* is a proprioceptive horizontally pivoted platform that creates instability conditions on the anteroposterior and lateromedial planes. It is a tool used for assessing dynamic posture, which allows knowing the sensory mechanisms that intervene in the balancing processes (Bessou, Joffroy, Montoya & Pages, 1990).

- *Optical Target* to be placed on a plane orthogonal to the subject at a distance of 240 cm (Kapoula, & Lê, 2006).

- *Forex Template* to always position the subject at the same distance from the webcam when assessing the scapular plane and performing the stabilomeric assessment.

***- Stabilometry***

- *Cyber-Sabots*$^{TM}$. was used for postural assessment (Gagey, Bourdeaux & Gagey, 2015; Bessou, Joffroy, Montoya & Pages, 1990). The force vectors that are applied to the pressure surface are converted into electrical signals and processed by special software that, by means of appropriate analyzes, obtains the specific values (Rossato, Bourgeois & Ouaknine, 2013). Compared to traditional stabilometric platforms, this separate foot platform is able to catch the difference in pressure due to laterality. Through the data provided, we have the opportunity to interpret the role played by the ankle and the hip in the postural control (Ouaknine & Bourgeois, 1998).

Static stabilometry records the body movements in an orthostatic position; it is maintained for 51.2 seconds, a sufficient time to assess strategies without resulting in the person's fatigue (Rossato, Nart, Biancalana & Scarpa, 2019; Gagey et al, 1995). Dynamic stabilometry in an orthostatic position allows studying the compensation mechanisms of the tonal asymmetries of the postural system; the duration of 25.6 seconds is a time sufficient to avoid creating fatigue responses on the part of the subject.

Dynamic stabilometry with proprioceptive insole allows triggering correction reflexes, thus causing changes in the activation of ascending proprioceptive chains (Bourdiol, Cappelòus, Nguyen Tan & Hatoum, 1980). The presence of insole under the feet affects the parameters involved in muscle work (Gagey & Weber, 2000).

## Statistical analysis

The statistical program used was GraphPad PRISM 7. We proceeded with the Paired T-test to highlight the presence of significant differences between the data acquired at T0 and at T1 following the 12 weeks' training. The statistical significance regarding the parameters considered was fixed at p-value $\leq 0.05$.

For an initial observation, the following parameters were taken into consideration:

- **X mean-Y mean (Xmoyen-Ymoyen)** are the coordinates of the midpoint of the Pressure Centre b (CdP). Xmoyen stands for the mean position on the X axis and expresses the oscillations on the frontal plane (right-left). Ymoyen stands for the mean position on the Y axis and describes the oscillations on the sagittal plane (antero/position). The components of the CdP may highlight an orthostatic asymmetry on the anteroposterior and/or mediolateral plane (Rossato, Bourgeois & Ouaknine, 2013).

- **Area (Surface)** is the ellipse containing 90% of the recorded points of the CdP. It is the statokinesigram which expresses the degree of oscillation of the Postural System. A particularly small area could mean a state of rigidity (Rossato, Bourgeois & Ouaknine, 2013).
- **Body weight distribution (AVG-TALG/AVD-TALD).** The stabilometric analysis allows detecting the load distribution of body weight between right and left forefeet (AVD-AVG) and right and left heels (TALD-TALG). This information allows checking the presence of asymmetries and represents the oscillation vectors on the ground (Rossato, Bourgeois & Ouaknine, 2013).
- **Speed Variation Index (IVV)** expresses the relationship between the activity of the left foot with respect to the right foot, allowing us to identify the "pivot foot" and "motor foot" considering the difference in energy expressed by them. The parameter can take values ranging from -1 to +1, where -1 refers to the left foot and +1 to the right foot. Please note that it is one of the parameters of automatic activity (Rossato, Bourgeois & Ouaknine, 2013).
- **Romberg's Quotient (QRBG)** indicates the relationship between the surface detected during the open-eyed acquisition and that obtained with the eyes closed. The value so obtained is the expression of how visual input affects posture (Rossato, Bourgeois & Ouaknine, 2013).

The mean (M) and the standard deviation (SD) were calculated for each parameter considered (Xmoyen, Ymoyen, Surface, VarVit, IVV), and the mean values so identified were compared whit the standard values assumed as a condition of normality (Rossato, Bourgeois & Ouaknine, 2013). This comparison showed that the values measured at T0 in the 2 groups (EG, CG) in the static open eyes (OE) and closed eyes (CE) mode, respectively, are within the sample mean as shown in Table 2 and in Table 3.

**Table 2:** Values of the variables considered in the 2 groups (EG; CG) at T0, in the OE static mode*.

| **Groups** | **stabilometric parameters (T0 – OE)** | | | | |
|---|---|---|---|---|---|
| | *Xmoyen* | *Ymoyen* | *Surface* | *VarVit* | *IVV* |
| **EG** | -0.25 ± 8.5 | 28.03 ± 18.02 | 133.97 ± 55.19 | 28.07 ± 11.9 | -0.01 ± 0.13 |
| **CG** | 1.34 ± 12.48 | 30.05 ± 11.88 | 155.27 ± 78.68 | 37.9 ± 31.82 | -0.1 ± 0.16 |

*Values are presented as mean ± SD.

**Table 3:** Values of the variables considered in the 2 groups (EG; CG) at T0, in the CE static mode*.

| **Groups** | **stabilometric parameters (T0 – CE)** | | | | |
|---|---|---|---|---|---|
| | *Xmoyen* | *Ymoyen* | *Surface* | *VarVit* | *IVV* |
| **EG** | -0.29 ± 7.9 | 30 ± 17.55 | 153.96 ± 106.55 | 54.22 ± 28.18 | 0.01 ± 0.12 |
| **CG** | 0.78 ± 12.15 | 33.49 ± 12.14 | 193.43 ± 153.97 | 80.42 ± 81.18 | -0.02 ± 0.12 |

*Values are presented as mean ± SD.

## Results

Among the variables considered, only the Surface and VarVit variables showed a statistically significant change.

***Surface variable***

Analysis of the data on the effect of proprioceptive training between T0 and T1 in the **EG** group showed a reduction at T1 (308.5 ± 205) compared to T0 (356.5 ± 232.1), although statistically non-significant ($p > 0.05$) for the Surface variable in the OE dynamic mode (Figure 2). In the **CG** group in the same mode, a minimal and statistically non-significant reduction was highlighted ($p > 0.05$) between T0 (393.5 ± 215.5) and T1 (367.3 ± 154.3) (Figure 3).

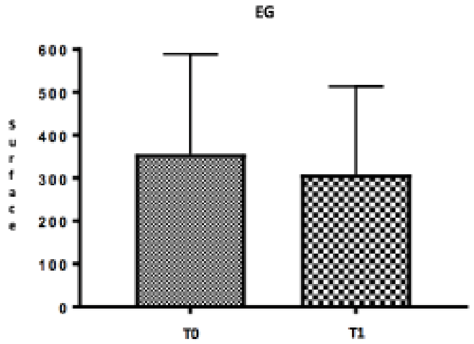


**Figure 2:** Data related to the EG group on the effect of proprioceptive training from T0 to T1 for the Surface variable in the OE dynamic mode. Data are represented using the arithmetic mean and standard deviation (significance = $p \leq 0.05$).

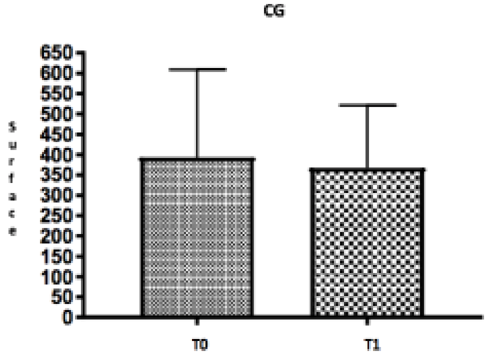


**Figure 3:** Data related to the CG group on the effect of proprioceptive training from T0 to T1 for the Surface variable in the OE dynamic mode. Data are represented using the arithmetic mean and standard deviation (significance = $p \leq 0.05$).

Analysis of the data on the effect of proprioceptive training between T0 and T1 in the **EG** group showed a statistically significant reduction (p = 0.01) at T1 (931.3 ± 580.6) compared to T0 (1655.7 ± 1059.2) for the Surface variable in the CE dynamic mode (Figure 4).
In the **CG** group in the same mode, a minimal and statistically non-significant reduction was highlighted (p > 0.05) between T0 (1669.8 ± 894.6) and T1 (1312.7 ± 398.6).

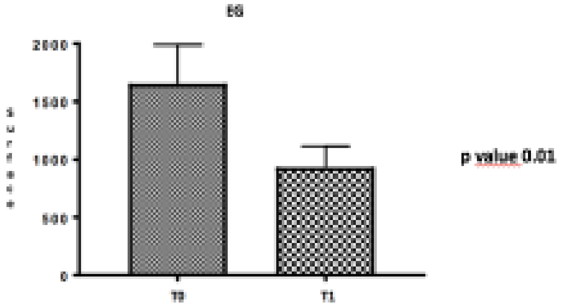


**Figure 4:** Data related to the EG group on the effect of proprioceptive training from T0 to T1 for the Surface variable in the CE dynamic mode. Data are represented using the arithmetic mean and standard deviation (significance = $p \leq 0.05$).

Analysis of the data on the effect of proprioceptive training between T0 and T1 in the **EG** group showed an increase at T1 (306.3 ± 198.5) compared to T0 (279.5 ± 142.3), although statistically non-significant (p > 0.05) for the Surface variable in the OE dynamic mode with proprioceptive insole (Figure 5).
In the **CG** group in the same mode too, a statistically non-significant increase was highlighted (p > 0.05) between T0 (343.9 ± 198.4) and T1 (354.6 ± 162.1) (Figure 6).

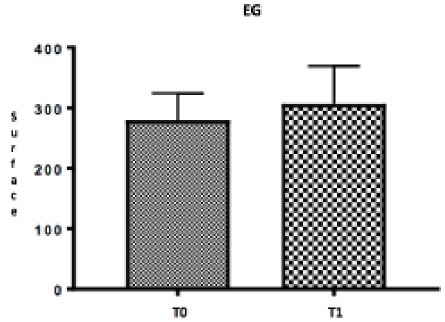


**Figure 5:** Data related to the EG group on the effect of proprioceptive training from T0 to T1 for the Surface variable in the OE dynamic mode with insole. Data are represented using the arithmetic mean and standard deviation (significance = $p \leq 0.05$).

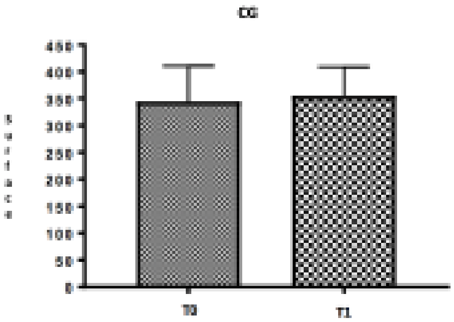


**Figure 6:** Data related to the CG group on the effect of proprioceptive training from T0 to T1 for the Surface variable in the OE dynamic mode with insole. Data are represented using the arithmetic mean and standard deviation (significance = $p \leq 0.05$).

Analysis of the data on the effect of proprioceptive training between T0 and T1 in the **EG** group showed a reduction at T1 (1034.1 ± 829.8) compared to T0 (1552.2 ± 941.2), although statistically non-significant (p > 0.05) for the Surface variable in the CE dynamic mode with proprioceptive insole (Figure 7).
On the contrary, in the **CG** group in the same mode, a statistically non-significant increase was highlighted (p > 0.05) between T0 (1092.4 ± 804.6) and T1 (1169.6 ± 896.5) (Figure 8).

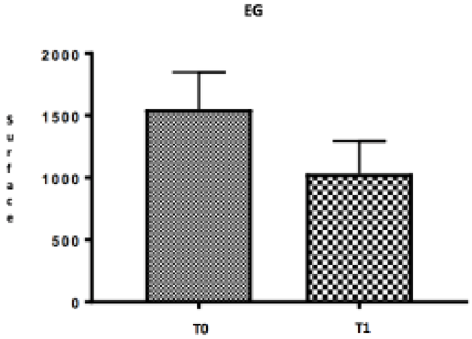


**Figure 7:** Data related to the EG group on the effect of proprioceptive training from T0 to T1 for the Surface variable in the CE dynamic mode with insole. Data are represented using the arithmetic mean and standard deviation (significance = $p \leq 0.05$).

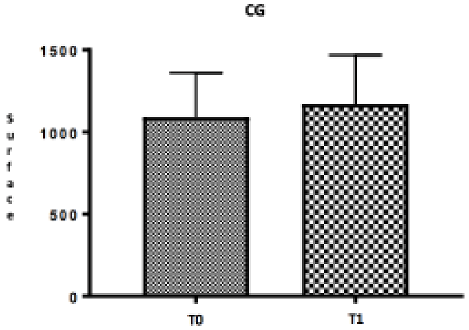


**Figure 8:** Data related to the CG group on the effect of proprioceptive training from T0 to T1 for the Surface variable in the CE dynamic mode with insole. Data are represented using the arithmetic mean and standard deviation (significance = $p \leq 0.05$).

***VarVit variable***

Analysis of the data on the effect of proprioceptive training between T0 and T1 in the **EG** group showed a slight increase at T1 (139.9 ± 101) compared to T0 (135.2 ± 78.5), although statistically non-significant (p > 0.05) for the VarVit variable in the OE dynamic mode.

In the **CG** group in the same mode, a minimal and statistically non-significant reduction was highlighted (p > 0.05) between T0 (214.9 ± 126.8) and T1 (147.8 ± 47.2).

Analysis of the data on the effect of proprioceptive training between T0 and T1 in the **EG** group showed a statistically significant reduction (p = 0.07) at T1 (549.7 ± 338.1) compared to T0 (948.8 ± 763.8) for the VarVit variable in the CE dynamic mode (Figure 9).

In the **CG** group in the same mode too, a statistically significant reduction (p = 0.03 was highlighted) between T0 (1101.2 ± 529.4) and T1 (757.6 ± 266.6) (Figure 10).

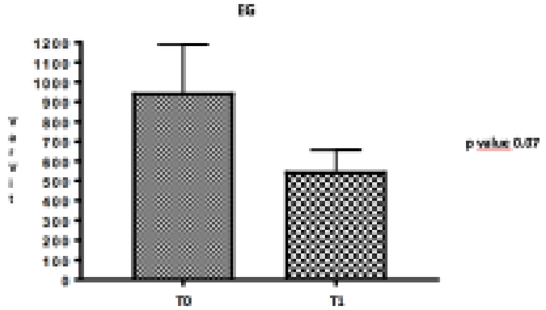


**Figure 9:** Data related to the EG group on the effect of proprioceptive training from T0 to T1 for the VarVit variable in the CE dynamic mode. Data are represented using the arithmetic mean and standard deviation (significance = *p* ≤ 0.05).

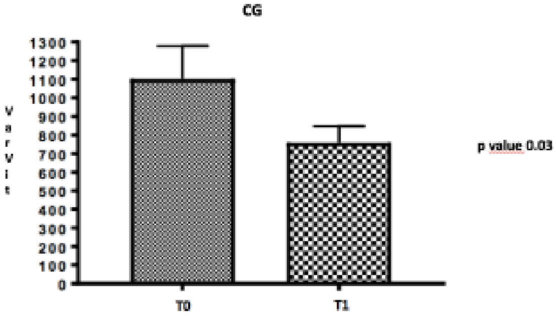


**Figure 10:** Data related to the CG group on the effect of proprioceptive training from T0 to T1 for the VarVit variable in the CE dynamic mode. Data are represented using the arithmetic mean and standard deviation (significance = *p* ≤ 0.05).

Analysis of the data on the effect of proprioceptive training between T0 and T1 in the **EG** group showed a statistically significant reduction (p = 0.03) at T1 (113,8 ± 73,8) compared to T0 (140.5 ± 91.3) for the VarVit variable in the OE dynamic mode with insole (Figure 11).

In the **CG** group in the same mode, a minimal and statistically non-significant reduction (p > 0.05) was highlighted between T0 (170.7 ± 114.3) and T1 (169.3 ± 65.8).

Analysis of the data on the effect of proprioceptive training between T0 and T1, in the CE dynamic mode with insole for the same variable, showed a statistically non-significant reduction (p > 0.05) in both groups.

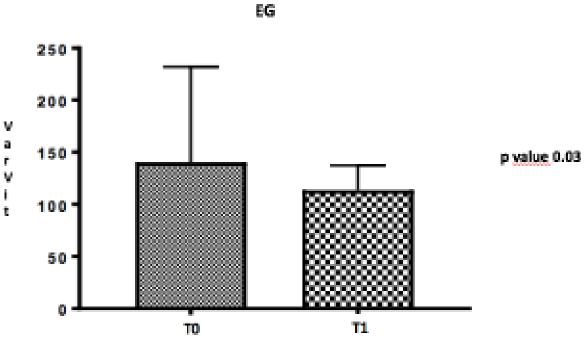


**Figure 11:** Data related to the EG group on the effect of proprioceptive training from T0 to T1 for the VarVit variable in the OE dynamic mode with insole. Data are represented using the arithmetic mean and standard deviation (significance = *p* ≤ 0.05).

## Discussion

From the results on the variables considered, it emerged that at T1 in the CE dynamic mode the value of the mean of the Surface variable in the EG group compared to the CG group was reduced in a statistically significant manner. This would seem to confirm the efficacy of proprioceptive training on the stability of the subjects, especially in the EC condition, in which the proprioceptive podalic sensitivity has a greater influence (Strzalkowski, Mildren & Bent, 2015). For the VarVit variable, the mean value, in the CE dynamic mode dropped in a statistically significant way in both groups, but more in the EG group. For the same variable in the EG group a statistically significant reduction was also determined in the OE dynamic mode with proprioceptive insole (Christovão et al, 2013; Gagey et al, 1995**)**. However, in the CG group, the use of proprioceptive insole proved to be effective, albeit with a minimal and non-significant reduction.

These results would seem to confirm the objectives of the study: to verify the effectiveness of proprioceptive training and to observe in the acute phase how the proprioceptive insole managed to trigger an immediate response of the myotatic reflex.

## Conclusion

The results obtained from the stabilometric parameters, which are beyond the subjects' control**,** show that some feet areas proprioception together with the control of the receptors located in the ankle are the afferents that evoke the myotatic reflexes necessary for posture stability (Yiou, Hamaoui & Allali, 2018).

The results of this study have shown that the proprioceptive training is efficient to change postural control in a real and stable way, to reduce the injury incidence in the elderly and to improve the life quality.

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