# Acute effect of partial body weight suspension on the level of cocontraction and gait biomechanics in women with knee osteoarthritis

*Efeito agudo da suspensão parcial de peso corporal no nível de cocontração e biomecânica da marcha em mulheres com osteoartrite de joelho*

*Efecto agudo de la suspensión parcial de peso corporal en el nivel de co-contracción y biomecánica de la marcha en mujeres con osteoartritis de rodilla*

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## Abstract

**Introduction:** Knee osteoarthritis (OAK) is one of the most prevalent rheumatic diseases in the population, characterized by functional limitation and gait difficulties with profound clinical relevance, as walking is the most frequently performed daily activity. These functional limitations may be more pronounced when the disease is associated with obesity. **Objective:** To investigate the effect of different body weight suspension percentages on gait biomechanical variables and co-contraction percentages in women with OAK. **Method:** Fourteen women aged 50-75 years, with a body mass index between 26 and 35 and radiological diagnosis of OAK participated in the study. On the first day, anamnesis and familiarization with

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gait on the treadmill was performed. On the second day, treadmill gait assessment was performed using partial body weight support (SPPC) in three conditions—15%, 30%, and 45% suspension. During the evaluation, electromyographic and kinematic data were collected. The variables analyzed were percentage of hip (gluteus maximus/rectus femoris), knee (femoral biceps/vastus lateralis), and ankle (anterior tibial/lateral gastrocnemius), and length and step widths. A one-way analysis of variance was conducted, with a significance level of $p < 0.05$. **Results:** There was no significant difference in the length and step width and the level of co-contraction between the running conditions analyzed. **Conclusion:** Body weight suspension using SPPC during treadmill running did not alter the biomechanical variables of the gait of women with OAK.

**Keywords:** Electromyography. Aged. Biomechanical Phenomena. Rheumatic Diseases.

### Resumo

***Introdução:*** *A osteoartrite de joelho (OAJ) é a uma das doenças reumáticas mais prevalentes na população, caracterizada por causar limitação funcional, sendo as dificuldades de marcha de grande relevância clínica por ser a atividade diária mais realizada. Essas limitações funcionais podem ser mais acentuadas quando a doença está associada a obesidade.* ***Objetivo:*** *Investigar o efeito de diferentes porcentagens de suspensão do peso corporal no percentual de cocontração e nas variáveis biomecânicas da marcha em mulheres com OAJ.* ***Método:*** *Estudo transversal no qual participaram do estudo 14 mulheres com idade entre 50-75 anos, IMC entre 26-35, com diagnóstico radiológico de OAJ. No primeiro dia foi realizado anamnese e familiarização da marcha na esteira. No segundo dia, foi realizado avaliação da marcha em esteira utilizando suporte parcial de peso corporal (SPPC) em três condições: 15%, 30% e 45% de suspensão. Durante a avaliação foram coletados dados eletromiográficos e cinemáticos. As variáveis analisadas foram: percentual de cocontração do quadril (glúteo máximo/reto femoral), joelho (bíceps femoral/vasto lateral) e tornozelo (tibial anterior/gastrocnêmio lateral); comprimento e largura do passo. Para análise estatística foi aplicado o teste Anova One Way, com nível de significância de p<0,05.* ***Resultados:*** *Não houve diferença significativa para o comprimento e largura de passo, assim como para o nível de cocontração entre as condições de marcha analisadas (p>0.05).* ***Conclusão:*** *A suspensão do peso corporal usando SPPC durante a marcha em esteira não altera o percentual de cocontração e as variáveis biomecânicas da marcha de mulheres com OAJ.*

***Palavras-chave:*** *Eletromiografia. Idoso. Fenômenos Biomecânicos. Doenças Reumáticas.*

### Resumen

***Introducción:*** *Una de las enfermedades reumáticas más prevalentes en la población, la osteoartritis de rodilla (OAJ) se caracteriza por causar limitación funcional, siendo las dificultades de marcha de gran relevancia clínica por ser la actividad diaria más realizada. Estas limitaciones funcionales pueden ser más intensas en asociación con la obesidad.* ***Objetivo:*** *Investigar el efecto de diferentes porcentajes de suspensión de peso corporal sobre las variables biomecánicas de la marcha y el porcentaje de cocontracción en mujeres con OAJ.* ***Método:*** *Participaron en el estudio 14 mujeres con edad entre 50-75 años, IMC entre 26-35, con diagnóstico radiológico de OAJ. En el primer día se realizó anamnesis y familiarización de la marcha en la cinta de correr. En el segundo día, se realizó una evaluación de la marcha en la cinta utilizando soporte parcial de peso corporal (SPPC) en tres condiciones: 15%, 30% y 45% de suspensión. Durante la evaluación se recogieron datos electromiográficos y cinemáticos. Las variables analizadas fueron: porcentaje de cocontracción de la cadera (glúteo máximo/recto femoral), rodilla (bíceps femoral/vasto lateral) y tobillo (tibial anterior/gastrocnémio lateral); longitud y anchura del paso. Para el análisis estadístico se aplicó la prueba Anova One Way, con un nivel de significación de p <0,05.* ***Resultados:*** *No hubo diferencia significativa para la longitud y anchura del paso, así como para el nivel de cocontración entre las condiciones de marcha*

*analizadas.* **Conclusión:** *La suspensión del peso corporal con SPPC durante la marcha en cinta no alteró las variables biomecánicas de la marcha de mujeres con OAJ.*

**Palabras clave:** *Electromiografía. Anciano. Fenómenos Biomecánicos. Enfermedades Reumáticas.*

## Introduction

Osteoarthritis is the second most common chronic disease that affects the population. It is a major cause of dysfunction and a health condition that advances quickly [1]. Among the affected joints, the knee (OAK) has a higher incidence of osteoarthritis [2]. In Brazil, approximately 5% of the population aged 30 to 59 years reports a medical diagnosis of osteoarthritis. In individuals aged 60 to 74 years, the prevalence reaches 16% [3].

OAK has a multifactorial etiology, with obesity proposed as the main risk factor for its development because of biomechanical and biochemical changes [4,5]. Regarding biomechanics, Bindawas and DeVita showed that the load imposed on the knee is proportional to the body mass [6,7]. Messier, in contrast, identified that each kilogram of body mass increases the compressive load on the knee by 4 kg during the performance of daily activities. The author concluded that excess body weight contributed to the degeneration of the joint structure of the knee [8]. In addition, the systemic increase in inflammatory cytokines secreted by adipose tissue, such as leptin and interleukin, also favor greater joint wear and contribute to a higher incidence of OA in obese people [9].

OAK and obesity affect the performance of several daily tasks, including walking. The ability to walk is a complex motor task, and its' performance in an efficient and safe way is an important prerequisite for maintaining independence [10].

Studies by Maclean and Houston illustrated that obese individuals with OAK show, alongside reduced gait speed, an increased support phase, and less range of motion of the knee. This is a strategy to reduce the load imposed on the joint when walking [11,12]. These biomechanical changes in the gait pattern can negatively affect the functional mobility of these individuals [8,12].

The increase in muscle co-contraction is also an important feature of gait in individuals with OAK. According to Preece et al., the simultaneous activation of agonist and antagonist muscles can be understood as an attempt to increase dynamic joint stability during the performance of a certain task [13]. However, in the long run, it can increase the compressive load because it generates approximation of the joint surfaces , thus, accelerating the disease's progression [5].

Excess body mass can cause biomechanical changes in lower limb joints, especially in individuals who have degenerative joint pathologies such as OA, which consequently change the gait pattern. The mechanisms that link OAK, obesity and gait are not fully understood, but literature shows that the loss of 34% of body mass in obese individuals reduces 67% of the compressive load on the knee, facilitating gait performance [7].

Partial body weight support (SPPC) is a therapeutic resource used to facilitate walking. The mechanism that generates this motor response is the reduction in body weight, which facilitates the movement of the lower limbs. It is associated with the continuous movement on a treadmill and the repetition of steps that stimulate the neural circuits of locomotion control, favoring the process of neural plasticity. Although its effects are better known in populations with neurological diseases such as spinal cord injury and Parkinson's, when considering the effect that obesity can have on gait variables in patients with OAK, this resource could contribute to gait training for these individuals.

Thus, this study sought to analyze how body weight influences the level of co-contraction of the joints of the lower limb and the kinematic variables of gait in individuals with OAK through the immediate suspension of the torso using partial body weight support (SPPC).

The hypothesis of this study is that the use of SPPC will provide a reduction reduce muscle co-contraction of the lower limbs and increase the length and width of the step during gait because of the reduced body weight.

## Method

### Participants

This is a cross-sectional study with 14 women. They were recruited by convenience sampling and diagnosed with knee osteoarthritis, according to the criteria of the American College of Rheumatology, as shown in Table 1.

Table 1 – Subjects characteristics

| | |
|---|---|
| Age (years) | 68.5 ± 7.3 |
| Weight (kg) | 76.9 ± 9.4 |
| Height (m) | 1.57 ± 0.06 |
| BMI (kg/m$^2$) | 31.14 ± 2.9 |
| Gait Speed (km/h) | 4.10 ± 0.7 |

The eligibility criteria included female participants aged between 50 and 75 years, body mass index between 26 and 35 kg/m$^2$, independent walking without the use of auxiliary devices, no other lower limb diseases, no cardiovascular or respiratory changes in the past 6 months, and the ability to respond to verbal commands. Physical activity was not adopted as a criterion.

The present study was submitted to the local ethics committee (2,611,288/18) and all participants signed an informed consent form.

### Assessment Procedures

The evaluation process was carried out in two days. On the first visit to the laboratory, anamnesis was conducted to collect anthropometric data and participants were familiarized with the treadmill gait test. On the second day, a gait assessment was initiated using partial body weight support (SPPC) and collection of the electromyographic and kinematic data was completed.

### Determination of Track Speed

To stablish the speed preference on the treadmill, the preferential speed of walking on the ground (VPMS) of each volunteer was initially determined. Thus, they were instructed to walk normally on a 10 meter long track, for 3 consecutive times. From 50% of the VPMS of each volunteer, a gradual increase of 0.1 km/h in treadmill speed was performed until the volunteer reported that the speed "is fast". Subsequently, the speed was gradually reduced (0,1 km/h) until the volunteer reported that the treadmill speed was slow. This protocol was repeated three times and the average of the three fastest and slowest speeds was considered the preferred speed of walking on the treadmill (VPME). The volunteers were familiarized with this speed for 10 minutes [14].

### Electromyography

The electromyographic signal was collected during the gait on the treadmill to assess the level of co-contraction of the muscles of the hip, knee, and ankle.

Even in volunteers with bilateral involvement of the muscles, the electrodes were affixed to the right lower limb of the gluteus maximus (GM), rectus femoris (RF), biceps femoris (BF), vastus lateralis (VL), lateral gastrocnemius (GL), and tibia (TA), according to Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM) rules.

To capture the electromyographic signals, an 8-channel biological signal acquisition module (Myosystem-BR1), Myosystem-BR1 software, calibrated with a sampling frequency of 2000 Hz, a total gain of 2000 times (20 times in the sensor and 100 equipment), a 20 Hz high-pass filter, and a 500 Hz low-pass filter were used.

Active electrodes were used in a bipolar configuration, with a capture area of 1 cm in diameter and an inter-electrode distance of 2 cm. To avoid possible interference with the electromyographic signal, a trichotomy was performed, and the skin cleaned with alcohol prior the electrodes placing. [15].

### Kinematics

For the collection of kinematic data, two Sony® cameras were used, positioned 1.5 m lateral and posterior to the treadmill and with a sampling frequency of 60 Hz, and photoreflexive markers were fixed at the following anatomical points: the lateral malleolus, the base of the second toe of both feet, and the calcaneus [16].

### Gait assessment

Gait assessment with SPPC was performed on a Millennium Super ATL treadmill (INBRAMED). The volunteers used a seat belt (parachutist) connected to a safety cable to prevent falls. They walked at the pre-established speed. Manual support for all volunteers was standardized. The following four walking conditions were assessed:

• Normal walking without body mass support;
• Normal gait with support of 15% of body mass;
• Normal gait with support of 30% of body mass;
• Normal gait, with support of 45% of body mass.

The volunteers were instructed to walk similarly to when performing daily activities for three minutes in each condition at walking speed preference on the predetermined treadmill. The electromyographic data were collected at the last minute. The order in which the proposed walking conditions were carried out was determined by means of directed randomization.

The percentage of suspension of body weight was controlled with the use of a load cell (EMG System do Brasil®) attached to the suspension belt.

## Data analysis

### Electromyographic signal

The electromyography data were processed using routines developed in a MATLAB environment (Mathworks®), and 10 consecutive gait strides considered for analysis. The signals were rectified and smoothed, using a 4th order low pass filter with a 6 Hz cutoff frequency.

The calculation of the percentage of co-contraction between the GM and RF, the RF and BF, the VL and BF, and the TA and GL muscles was performed from the linear envelope values, according to the equation below, as proposed by Winter and Candotti [17,18].

$$\%COCON = 2 \times \frac{common\ area\ A\ \&\ B \times 100}{area\ A + area\ B}$$

The *%COCON* is the percentage of co-contraction between two antagonistic muscles A and B, such as VM and BF. Area A is the smoothed curve of the EMG activity of muscle A, and area B is the smoothed curve of the EMG activity of muscle B. The common area A&B is the common curve of the EMG activity of muscles A and B [17,18].

### Kinematics

To analyze kinematic gait variables, the Peak Motus Motion Measurement System (VICON®), version 9.0 of a 2-D analysis, was used. This allows the positioning and displacement of body segments to be registered, from the marking of joint points and subsequent data analysis.

The step length was determined as the distance between the marker placed on the second toe and heel, and the step width calculated by the distance between the markers placed on the heel [16].

### Statistical analysis

Statistical analysis was performed using the PASW Statistics 18.0® (SPSS) software. After checking the normality and homogeneity of the data using a Shapiro-Wilk test, a one-way analysis of variance was conducted to compare the percentage of co-contraction and kinematic variables during the four walking conditions. In all statistical tests, a significance level of $p < 0.05$ was adopted.

## Results

The one-way analysis of variance showed no significant difference between the gait conditions analyzed for the percentage of co-contraction of the GM-RF muscles (F = 0.112, $p = 953$), VL-BF (F = 0.023, $p = 0.995$) and TA-GL (F = 1.289, $p = 0.228$), as shown in Table 2. Regarding the kinematic variables, there was no significant difference in the step length (F = 0.748, $p = 0.529$) and step width (F = 0.500, $p = 0.684$).

**Table 2** – Biomechanical gait variables in different conditions of body weight support

|  | Normal Gait | 15% | 30% | 45% |
|---|---|---|---|---|
| GM/RF | 71.45 ± 19.3 | 72.0 ± 15.57 | 69.95 ± 19.2 | 73.92 ± 18.8 |
| BF/VL | 77.77 ± 12.4 | 77.64 ± 15.8 | 76.53 ± 17.1 | 77.88 ± 15.7 |
| GL/TA | 78.55 ± 14.0 | 70.63 ± 15.2 | 75.23 ± 14.8 | 79.98 ± 10.0 |
| Step length (m) | 0.68 ± 0.05 | 0.67 ± 0.06 | 0.67 ± 0.05 | 0.65 ± 0.05 |
| Step width (m) | 0.18 ± 0.03 | 0.17 ± 0.04 | 0.18 ± 0.03 | 0.19 ± 0.04 |

Note: Mean values ± standard deviation. GM/RF: gluteus maximus/rectus femoris; BF/VL: biceps femoris/vastus lateralis; GL/TA: gastrocnemius lateralis/tibialis anterior.

## Discussion

This study had as its initial hypothesis that the reduction in body weight would decrease the percentage of lower limb co-contraction and increase the length and width of the step with the decrease in body weight of women with OAK during their gait. However, the hypothesis was refuted. Despite studies showing that body weight influences the biomechanical factors of gait, the temporary and acute reduction of these variables with SPPC was insufficient to change the gait pattern of the volunteers.

According to the literature, female gender and obesity are the main risk factors for OAK and are related to biomechanical changes in the gait pattern [8,19], with obese women being four times more likely to develop OAK [20]. Women lose cartilage faster than men after 40 years of age and have greater knee valgus angulation, which contributes to the asymmetric distribution of joint loads [21,22]. In contrast, obesity is a risk factor that can be modified in this population. Devita showed that a loss of 34% of body mass in obese individuals reduces in 67% the compressive load on the knee, which could contribute to a more efficient gait pattern [7].

The reduction in body mass of the participants in this study was provided by SPPC, which is used as a gait training tool for different populations through the suspension of the torso. According to the literature, this equipment favors the execution of gait because it reduces the load imposed on the joints of the lower limbs, allowing a wider movement and providing more appropriate sensory feedback [23,24].

Although the study did not find significant differences in the variables analyzed, the use of SPPC can, in the long run, favor the execution of gait. The stimuli of the treadmill facilitate movement, the beginning and continuation of gait, and the increase in steps size. This type of training stands out for its' specificity in improving gait at a constant speed with regular sensory stimulation, visual feedback and activation of a neuronal circuit that generates central gait patterns. These work independently of the motor cortex and can produce rhythmic movements, resulting in motor learning. For the patient population with OAK, walking is one of the most compromised activities of daily living, impairing their independence . The motor learning generated by gait training with SPPC could be a tool to improve the gait speed of patients with OAK and consequently the level of functional mobility.

Regarding the gait neuromuscular characteristics, Amiri states that there is an association between obesity and muscle activation when identifying the sustained activation of the gastrocnemius and quadriceps muscles during the gait support phase in individuals with OAK classified as obese compared to those classified as overweight and normal weight [5]. This change in the pattern of muscle activation can occur as a compensatory strategy, that is, individuals with OAK have greater joint instability and consequently generate greater muscle activation to stabilize the knee joint during daily tasks [25].

The increase in co-contraction is observed in patients with OAK regardless of the severity of the disease and aims to reduce the load on the knee and increase dynamic joint stability [5]. By reducing the body weight of volunteers with SPPC, a decrease in the percentage of activation of the agonist and antagonist muscles was expected, given that the joint overload was reduced. Three minutes may have been insufficient to alter the pattern of neuromuscular activation of their gait.

The present study did not analyze the phases of gait (support/swing) separately because the joint overload changes in these moments, which

is greater when the limb not affected by the disease finds the balance sheet phase, what may have influenced the electromyographic results.

Despite the study not showing differences in muscle co-contraction with a reduction in body weight, literature shows that the effects generated by co-contraction for a prolonged period can contribute to the loss of cartilage and accelerate the evolution of the disease [26]. Co-contraction can also affect movement efficiency and load distribution in the joint, negatively affecting the functional mobility of individuals with OAK [27].

Regarding gait kinematics, the present study did not find significant differences in step width and length during the various gait conditions with the suspension of body weight. During gait, the loads to which the knee is exposed are the result of external forces (gravity and ground reaction force) and are almost always dependent on body weight. In an orthostatic position, this is equivalent to approximately 43% of body weight, which influences the gait pattern [8]. By reducing body weight with SPPC, the ground reaction force imposed on the joints of the lower limbs also decreases, which could favor gait execution. However, this was not observed in the present study.

Hamu reported that obese women have lower step length values when walking than eutrophic women [28]. Pivetta et al. compared the temporal space characteristics of gait between obese and eutrophic individuals and found a difference in step width during walking [29]. These changes in gait pattern can be interpreted as a strategy to reduce pain and, consequently, an overload is imposed on the knee with OA [30].

The kinematic analysis in this study was carried out on a treadmill, which is characterized by the constant maintenance of walking speed imposed by the device's rhythm . This mechanism induces an increase in the step length because, while the lower limb is brought back, the hip flexors are stretched, activating the muscle spindles, and consequently maximizing this muscle group performance and contributing to a more regular gait pattern. [16].

Studies show that gait training with SPPC can effectively modify the gait pattern of various populations, including neurological and orthopedic patients. However, most studies observe 20-30 minutes of walking on the treadmill, per session [16,24]. In the present study, the volunteers walked for three minutes for each proposed condition, which may have been insufficient to modify the biomechanical gait pattern, with no significant differences for the electromyographic and kinematic variables.

Bearing in mind that OAK has no cure and that changes in the neuromuscular and kinematic gait pattern are progressive, this condition can be aggravated by excess body weight. New studies should be conducted with patients walking with SPPC for longer periods of time than the proposed in this study, assisting in the understanding of the influence of body weight on gait variables, thus proposing more effective intervention strategies for this population.

The authors emphasize the importance of verifying the influence of body weight on biomechanical gait variables in order to establish clinical intervention strategies to improve gait patterns and, consequently, reduce the risk of functional disability and falls in the OAK population.

## Study limitations

The present study was limited by the walking time with SPPC proposed for each gait condition analyzed, suggesting the need to analyze the effect of this training for a longer time period. In addition, there was no control group in order to compare the neuromuscular behavior during body weight reduction. This could assist in the understanding of the compensatory mechanisms used by the population with knee osteoarthritis.

## Conclusion

The reduction in body weight provided by the suspension of the torso using the SPPC for three minutes in each of three different conditions, was not enough to reduce the level of co-contraction in the joints of the lower limb and change the length and width of the step during gait walking in women with knee osteoarthritis.

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