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Synchronized Cyclograms to Assess Inter-Limb Symmetry during Gait in Women with Anorexia and Bulimia: A Retrospective Study

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Abstract: Anorexia nervosa (AN) and bulimia nervosa (BN) are eating diseases characterized by extreme eating behaviours impacting both mental and physical health. Aberrant musculoskeletal adaptations due to malnutrition affect motor abilities such as postural control and gait. To date, limited data is available with regards to gait symmetry in AN and BN. The aim of this study was to characterize inter-limb asymmetry during gait in two cohorts affected by AN and BN, respectively, using the synchronized cyclograms and to compare it with a healthy weight group. A total of 14 AN, 17 BN, and 11 healthy-weight females were assessed via 3D gait analysis. Gait spatio-temporal parameters were computed together with angle–angle diagrams, which were characterized in terms of their geometric features. Individuals with AN and BN were characterized by reduced speed and cadence and an abnormal increase in the duration of the double support phase with respect to the healthy controls. With respect to inter-limb symmetry, asymmetries were detected in both groups, with individuals with BN exhibiting significantly larger cyclogram areas at the hip joint with respect to the other groups (323.43 degrees^2 vs. 253.74 degrees^2 vs. 136.37 degrees^2) and significantly higher orientation angle and Trend Symmetry at both knee and ankle joint. The cyclogram analysis suggests the presence of an altered gait symmetry in individuals with BN. In the AN group, it is possible to observe a similar trend; however, this is not statistically significant. Overall, the findings of this study may provide a novel perspective on the motor control dysfunction linked to eating disorders and aid clinicians in selecting a suitable rehabilitation scheme targeted at enhancing motor stability and control.

Keywords: eating disorders; anorexia; bulimia; gait; kinematics; symmetry; rehabilitation

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1. Introduction

Eating disorders (EDs) are life-threatening syndromes characterized by extreme behaviors that can lead to significant impairments in both physical and mental health [1]. Distorted body shape perception and attitudes towards obsessive weight control play a key role in the onset of an ED, which mainly occurs in early-to-late adolescence [2], but it can also present across the entire lifespan [3,4] in both males and females [5,6]. Recent findings showed that the lifetime prevalence rates of anorexia nervosa (AN) might be up to 4% among females and 0.3% among males; regarding bulimia nervosa (BN), up to 3% of females and more than 1% of males suffer from this disorder during their lifetime [7]. The wide range of complications and comorbidities associated with EDs, either in the physical or psychiatric sphere [8–11], severely impact the quality of life and social function [12,13]. Among the recognized EDs, AN and BN are the most widespread [9,12] both in adolescents and young adults [14,15].

AN is characterized by self-starvation, leading to severe underweight as well as the adoption of behaviors preventing weight gain, such as compulsive exercise [16]. Due to its impact on the cardiovascular system [17] and increased suicide tendencies [18], AN is associated with the highest mortality rate among EDs [7]. In terms of prognosis, about 50% of affected individuals achieve full recovery and 30% improve, whilst 20% remain chronically ill [14,19]. On the contrary, those with BN are usually not underweight, but they experience continuous cycles of binge eating and purging accompanied by recurrent compensatory behaviors (i.e., self-induced vomiting, abuse of laxatives and diuretics, fasting, and excessive exercise) that may lead to severe dysfunctions of the digestive system and electrolyte and chemical imbalances. Such issues negatively affect several important organ functions [12,15].

However, it is noteworthy that both conditions have the potential to deteriorate the overall body motor functions; significant weight loss or excessive gains may contribute in fact to central and peripheral disorders, leading to aberrant musculoskeletal adaptations [20], impaired performance of the sensorimotor system, and, eventually, disability [21]. In this context, functional motor assessment in AN and BN might contribute to raising awareness for specific impairments associated with such conditions and specifically address them with tailored training or rehabilitation programs.

To date, motor functions mainly assessed in individuals with AN and BN are gait and postural control, which are performed with marker-based optoelectronic motion capture (MoCap) systems. In particular, it was observed that individuals with BN are characterized by balance impairments that may increase the risk of falling compared to healthy individuals [22]. Indeed, during assessment under two quiet-standing conditions (i.e., eyes open and eyes closed), young females with BN exhibited greater displacement of the center of mass (CoM). This displacement, particularly in the antero-posterior direction, was more pronounced compared to an age-matched control group with a healthy weight. Interestingly, no significant alterations of CoM excursion were observed in a group of women with AN. Consequently, it can be hypothesized that musculoskeletal factors associated with body weight fluctuations play a significant role in reduced postural control rather than absolute Body Mass Index (BMI) values [22]. With respect to gait, in both Eds, the pattern was found to be significantly impaired with respect to healthy individuals [21]. In particular, those with ED exhibited reduced step length and speed as well as altered kinematics at the hip and pelvis level on the sagittal and frontal plane as a result of neuromuscular adaptations [21,23]. For instance, in individuals with BN and AN, increased pelvis range of motion (ROM) in the transversal plane due to pelvic anteversion was observed, resulting in increased hip flexion in the frontal plane. In particular, in those with BN, the forward pelvic tilt is caused by the increased shear torque on the lumbosacral spine due to cyclic body weight gain and abdominal fat, whilst in AN it is mainly caused by the reduced tone and strength of the spinal and pelvic muscles [21,24,25].

In contrast, scarce information is available on inter-limb coordination, which is the relationship between the position of limbs throughout the gait cycle [26]. Inter-limb coordination, which is one of the expressions of postural stability and is strictly implicated in the harmonious and optimized performance of both simple and complex motor tasks, can be evaluated through the analysis of symmetry. Although human gait is never perfectly symmetric, the existence of marked asymmetries has been associated with disturbances originating from either musculoskeletal anomalies or altered motor control. Thus, a proper assessment of symmetry may represent a tool to unravel coordination issues and their features.

The simplest approach to quantifying the symmetry of gait is based on the computation of discrete values computed according to the observed difference between the contralateral limbs in terms of spatio-temporal parameters [27]. Although convenient and easy to use, this technique does not consider the temporal evolution of the gait features and neglects kinematic aspects. To overcome such drawbacks, more complex methods relying on the lower limb kinematics [28] have been developed. Waveform-based methods exploit the whole kinematic data associated with a certain lower limb joint angle with time throughout the whole gait cycle and thus enrich the information content useful to quantify symmetry. This approach was successfully applied in the last decade to investigate inter-limb coordination in several pathologic populations affected by both neurologic (neuropathies, stroke, Parkinson's disease, and multiple sclerosis) [28–32] and orthopaedic conditions [33–35]. In most cases, the use of waveform-based methods resulted more effective in detecting subtle alterations of gait with respect to discrete symmetry indices. Among them, the measurement of relative joint motion (graphically expressed as a relative motion plot, angle–angle diagram, or cyclogram) represents the most widespread approach. In short, a cyclogram is a left–right diagram built using the angular position of two lower limb contralateral joints across the gait cycle, regardless of time, which allows for symmetry quantification through several geometrical or mathematical features [36,37].

Several studies pointed out that gait asymmetries are often associated with impaired balance and increased energy cost during locomotion [38,39], which is a combination of issues that increases the risk of falls with consequent traumatic injuries and fractures. In AN individuals, who are characterized by low bone mineral density due to the deprivation of vital substances for bone metabolism and skeletal health [40], falls are likely to result in clinically relevant fractures with long-term consequences and disability [41,42]. In addition, deviations in gait symmetries increase the metabolic and mechanical energy cost during walking [43], which can have important implications for patients with reduced caloric intake and impaired motor function. For these reasons, it appears important to investigate the effects of gait asymmetries in EDs. Due to the potential associated with the application of bilateral cyclograms, in this study, we propose a retrospective study that characterizes lower-limb asymmetries during gait in women with AN and BN, including comparisons with a control group (CG) of healthy-weight individuals. As individuals with AN and BN were previously demonstrated to present reduced gait smoothness and symmetry by applying other investigation methods [21], it was hypothesized that the application of cyclograms could uncover noteworthy elements related to inter-limb asymmetry in patients with EDs.

In this study, our sample is composed only of women, according to the availability of hospitalized individuals with a diagnosis of ED in San Giuseppe Hospital (IRCCS Istituto Auxologico Italiano, Piancavallo, Italy); this prevalence is in line with the literature that reported a higher incidence of EDs in females [7].

2. Materials and Methods

2.1. Participants

A total of 42 adult females, divided into three different groups, were recruited in this study on a voluntary basis and their characteristics are summarized in Table 1. Of them 14 were affected by AN (Anorexia Group: age: 33.0 (10.6) years; BMI: 16.0 (2.1) kg/m^2) and 17 by BN (Bulimia Group: age: 26.9 (8.3) years; BMI: 20.8 (3.2) kg/m^2).

All of them received a diagnosis of ED, specifically, anorexia nervosa (including the binge-purging subtype) and bulimia, through the EDI-3 test administered by a specialized physician and were hospitalized at San Giuseppe Hospital (IRCCS Istituto Auxologico Italiano, Piancavallo, Italy) for a nutritional rehabilitation program. All the patients were required to be free from cardiovascular, neurological, or orthopaedic conditions able to severely affect gait and postural control, as well as from psychiatric comorbidities. In addition, patients with severe malnutrition, defined by a BMI < 13 kg/m^2 were not considered eligible for this study. A group of 11 unaffected women recruited among the hospital staff served as controls (Control Group: CG; age: 41.3 (9.9) years; BMI: 21.7 (2.0) kg/m^2). They showed normal flexibility in all of the major joints, normal muscle strength in the lower limbs as assessed by manual muscle testing, normal balance score at the Tinetti scale, and no clinically evident gait abnormalities.

This study was approved by the Ethical Committee and conducted in accordance with the 1964 Helsinki Declaration and its latest amendments, as well as with the ethical standards of the institute. Written informed consent was signed by all participants.

Table 1. Anthropometric and clinical features of participants. Values are expressed as mean (SD). Univariate analysis of variance (ANOVA) was used to investigate the existence of possible differences in the demographic characteristics. Multivariate analysis of variance (MANOVA) was used to investigate the existence of possible differences between the anthropometric characteristics of the three groups.

	Anorexia (*n* = 14)	**Bulimia (*n* = 17)**	**Control Group (*n* = 11)**
Age	33.0 (10.7)	26.9 (8.4) [a]	41.4 (9.9)
Body Mass (kg)	42.5 (7.3) [a,b]	56.4 (8.6)	54.5 (6.1)
Height (cm)	162.9 (7.6)	164.7 (3.3) [a]	158.4 (5.0)
BMI (kg/m^2)	16.0 (2.1) [a,b]	20.8 (3.2)	21.7 (2.0)

The CI 95%, *p*-values were considered significant if $p < 0.05$ for ANOVA and $p < 0.017$ ($p < 0.05/3$ after Bonferroni correction) for MANOVA. The symbols [a] and [b] denote statistically significant differences between the control group and individuals with bulimia, respectively.

2.2. Methods

All participants underwent an instrumented 3D gait analysis (GA) at the Motion Analysis Laboratory of San Giuseppe Hospital. This facility is equipped with an optoelectronic BMI system composed of six cameras (VICON, Oxford Metrics Ltd., Oxford, UK; sampling rate: 100 Hz) and two force platforms (Kistler, Winterthur, CH). Prior to the GA execution, participants' anthropometric characteristics were collected (i.e., height, body weight, anterior superior iliac spine distance, pelvis thickness, knee and ankle width, and leg length). A set of 22 spherical retro-reflective markers were placed on specific anatomical landmarks on participants' bodies according to the set-up (Figure 1) proposed by Davis et al. [44]. In order to perform the GA, participants were asked to walk barefoot along an 8 m walkway at their natural pace. Each subject performed up to five trials in order to guarantee the reproducibility of the results in terms of kinematics.

2.3. Data Analysis

Raw data (i.e., 3D marker's trajectories) were processed using the dedicated motion tracking software Nexus (Nexus, version 1.8., Vicon, Oxford Metrics Ltd., Oxford, UK). Three out of five trials consistent in terms of spatio-temporal parameters and kinematics were selected for each participant and considered for further analysis. The selected trials were imported into the software module Polygon (Polygon, version 2.4, Vicon, Oxford Metrics Ltd., Oxford, UK) to compute the following variables:

Spatio-temporal gait parameters (i.e., gait speed, stride length, cadence, stance, and double support phase duration).

The dynamic range of motion (ROM) of hip, knee, and ankle joints is calculated as the difference between the minimum and the maximum flexion-extension angles (hip and knee) and dorsi-plantar flexion angle (ankle) observed during the gait cycle.

Hip, knee, and ankle kinematics in the sagittal plane (hip and knee flexion-extension and ankle dorsi-plantarflexion angles during the gait cycle). All the graphs obtained from the GA were normalized as % of the gait cycle.

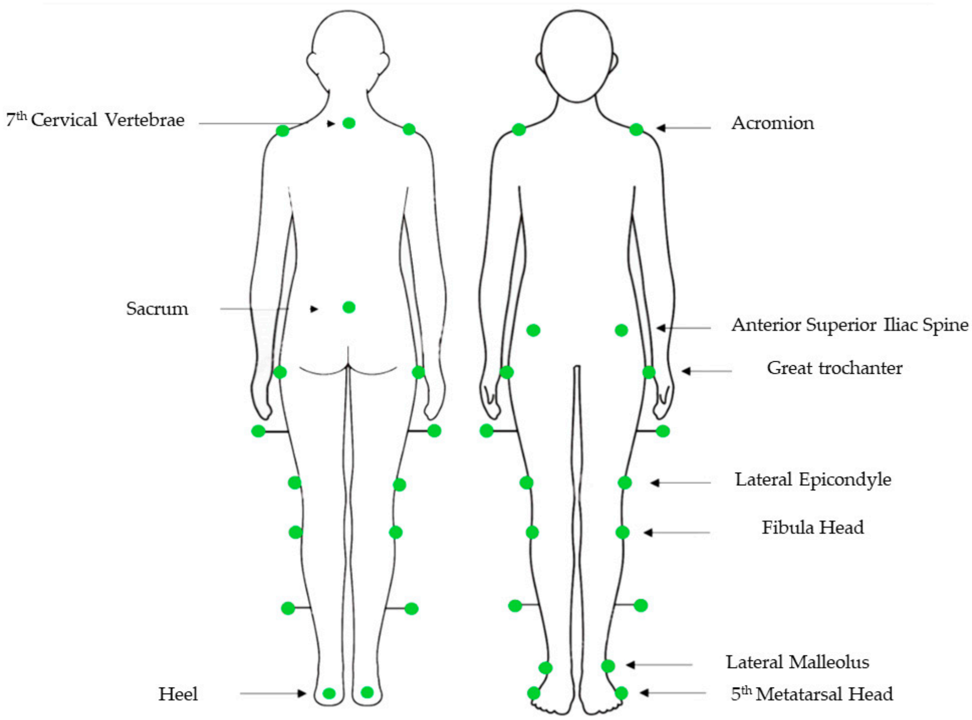

Figure 1. Markers' placement according to the Davis protocol [44].

Starting from the sagittal kinematics, the following bilateral cyclogram features (Figure 2) were computed through a dedicated script developed under Matlab environment (version R2023, The MathWorks Inc, Natick, MA, USA):

- Area (degrees^2) is defined as the area enclosed by the cyclogram [45]. When the gait is perfectly symmetric, left and right joints are in the same angular position during each gait phase, thus resulting in a null area. The more asymmetrical the gait, the more the area increases.
- Cyclogram orientation (φ, degrees) is calculated according to the procedure described by Goswami [36,37], which, in short, exploits the properties of generalized moments to identify and classify plane closed curves. In particular, orientation is computed as the absolute value of the angular difference between the 45° line (i.e., perfect symmetry) and the orientation of the principal axis of inertia of the cyclogram. High φ angles indicate reduced inter-limb symmetry.
- The Trend Symmetry Index (dimensionless) is calculated as described by Crenshaw et al. [46]. The index is computed through an eigenvector analysis and used to assess the similarity of the waveforms corresponding to right and left leg angular trends across the gait cycle for each joint. Trend Symmetry values increase together with gait asymmetries.

2.4. Statistical Analysis

The existence of possible differences in inter-limb coordination associated with the presence of ED was assessed using one-way multivariate analysis of variance (MANOVA) in which the participant's status (i.e., AN, BN, and CG) was the independent variable and dependent variables, respectively: the 7 spatio-temporal parameters, the 3 previously listed symmetry indexes at hip, knee, and ankle joints, and the 3 dynamic ROMs. The level of significance was set at $p = 0.05$, and the effect sizes were assessed using the eta-squared (η^2) coefficient. Univariate ANOVAs were carried out as a post-hoc test by reducing the level of significance to $p = 0.01$ (0.05/5) for spatio-temporal parameters and $p = 0.017$ (0.05/3) for the symmetry indexes and dynamic ROMs after a Bonferroni correction for multiple comparisons. All analyses were performed using the IBM SPSS Statistics v.20 software (IBM, Armonk, NY, USA).

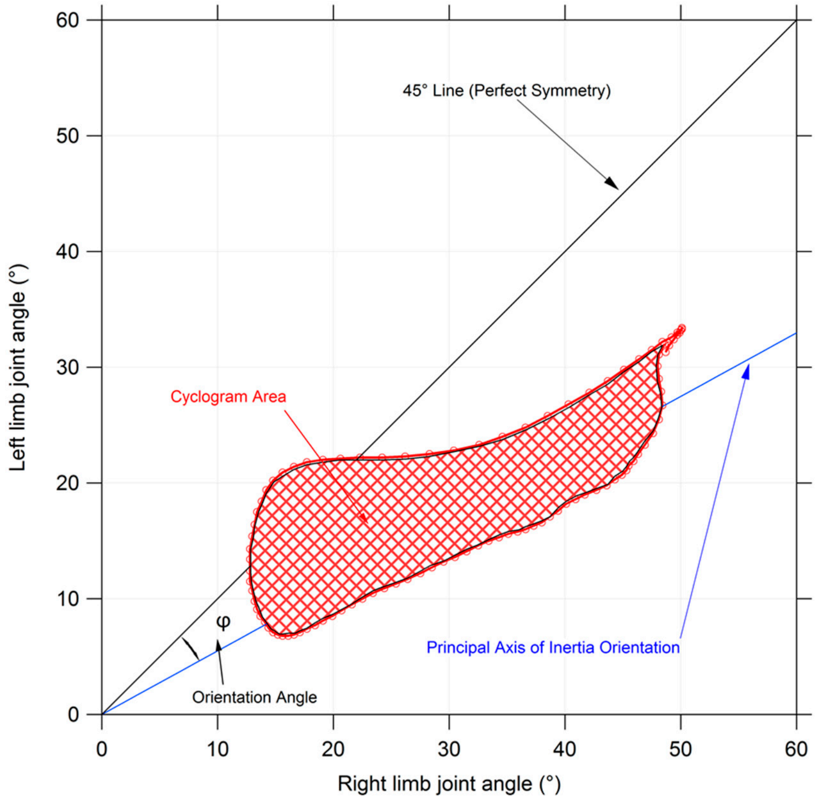

Figure 2. Graphical representation of a cyclogram and its main features considered for the present study.

3. Results

The comparisons between spatio-temporal parameters of gait, symmetry indexes, and dynamic ROMs across the three groups are summarized in Tables 2–4.

3.1. Spatio-Temporal Parameters of Gait

Table 2 reports the values of the spatio-temporal parameters calculated for the three groups analyzed. In particular, the statistical analysis found a significant main effect of group (F (10,70) = 16.64, $p < 0.001$, Wilks $\lambda = 0.09$, $\eta^2 = 0.70$) on spatio-temporal parameters of gait. From the follow-up analysis, it emerged that individuals with ED were characterized by significantly altered values of most investigated parameters, even though there were some differences. In fact, those of the AN group exhibit slightly yet significantly reduced speed (−12%, $p = 0.045$) and cadence (−8%, $p = 0.03$), with respect to unaffected individuals, and increased duration of double support phase (which resulted more than doubled, $p < 0.001$), with respect to both BG and controls. In contrast, those of the BG group were characterized by increased stance and double support phase duration, with respect to unaffected individuals. In both groups of individuals with ED, the step length was found to be shorter than the controls, but statistical significance was not achieved.

Table 2. One-way multivariate analysis of variance was used to investigate the existence of differences in spatio-temporal parameters of gait between healthy controls, individuals with anorexia, and individuals with bulimia. Values are expressed as mean (SD).

	Control Group	Bulimia	Anorexia
Gait speed (m/s)	1.35 (0.22)	1.27 (0.11)	1.18 (0.14) [a]
Step length (m)	0.66 (0.08)	0.65 (0.04)	0.63 (0.06)
Cadence (steps/min)	122.31 (7.81)	116.66 (6.98)	112.29 (7.08) [a]
Stance phase (% of GC)	58.33 (1.54)	60.10 (1.34) [a]	59.17 (1.43)
Double support (% of GC)	8.45 (1.92)	20.26 (2.60) [a]	19.30 (2.82) [a,b]

The 95% CI p-value was considered significant if $p < 0.01$ ($p = 0.05/5$ after Bonferroni correction). The symbols [a] and [b] denote statistically significant differences between healthy controls and individuals with bulimia, respectively. GC: Gait Cycle.

3.2. Dynamic ROM

Table 3 reports the dynamic ROM values calculated for the three groups. In this case, the statistical analysis did not detect any significant main effect associated with the group (F (6,74) = 0.61, $p = 0.717$, Wilks λ = 0.91, $\eta^2 = 0.05$).

Table 3. One-way multivariate analysis of variance was used to investigate the existence of differences in dynamic ROM between healthy controls, individuals with anorexia, and individuals with bulimia. Values are expressed as mean (SD).

	Control Group	Bulimia	Anorexia
Hip ROM (°)	48.63 (6.19)	45.90 (4.73)	45.47 (3.81)
Knee ROM (°)	64.16 (4.58)	61.27 (6.62)	62.11 (4.25)
Ankle ROM (°)	31.80 (5.66)	29.21 (5.75)	29.73 (4.02)

The 95% CI p-value was considered significant if $p < 0.016$ ($p = 0.05/3$ after Bonferroni correction).

3.3. Gait Symmetry Indexes

Table 4 reports the cyclogram's parameters for the three tested groups, while diagrams of Figure 3 show two examples of cyclograms calculated in the case of unaffected individuals compared with those with either anorexia or bulimia. Looking at the results, it is possible to observe that both AN and BG groups exhibited values of cyclogram parameters higher with respect to unaffected individuals (except for the case of the area at the knee joint). MANOVA detected a significant main effect of the individual's status on symmetry indexes in all three joints. In particular, for the hip (F (10,70) = 2.04, $p = 0.041$, Wilks λ = 0.60, $\eta^2 = 0.23$), for the knee (F (10,70) = 4.47, $p < 0.001$, Wilks λ = 0.37, $\eta^2 = 0.39$), and for the ankle (F (10,70) = 2.66, $p = 0.008$, Wilks λ = 0.52, $\eta^2 = 0.27$). However, the post-hoc analysis revealed that differences actually associable with the presence of ED involve the BG group only. In fact, the BG group was characterized by orientation and Trend Symmetry Indexes that were significantly higher with respect to the control group. Similarly, the mean values of the cyclogram area were found to be higher than those calculated for healthy individuals for all three joints; however, these differences were found to be significantly larger only at the hip level (323.43 vs. 136.37 degrees^2, $p = 0.027$). As regards the AN group, the post-hoc analysis did not detect significant alterations of any cyclogram's parameter with respect to the other two groups.

Table 4. One-way multivariate analysis of variance was used to investigate the existence of differences in symmetry parameters of gait between healthy controls, individuals with anorexia, and individuals with bulimia. Values are expressed as mean (SD).

Parameter	Joint	Control Group	Bulimia	Anorexia
Cyclogram area (degrees^2)	Hip	136.37 (99.79)	323.43 (236.07) [a]	253.74 (128.91)
Cyclogram orientation ϕ (degrees)		1.32 (1.03)	23.52 (19.89) [a]	14.85 (19.04)
Trend Symmetry		1.42 (1.03)	23.33 (19.77) [a]	14.72 (18.99)

Table 4. *Cont.*

Parameter	Joint	Control Group	Bulimia	Anorexia
Cyclogram area (degrees^2)	Knee	302.05 (163.48)	221.53 (182.96)	375.99 (291.99)
Cyclogram orientation ϕ (degrees)		1.77 (1.68)	24.18 (20.35) [a]	13.64 (18.11)
Trend Symmetry		1.81 (1.71)	24.20 (20.31) [a]	13.36 (18.27)
Cyclogram area (degrees^2)	Ankle	68.35 (71.35)	87.74 (51.07)	125.91 (73.64)
Cyclogram orientation ϕ (degrees)		3.50 (2.72)	27.47 (21.51) [a]	17.20 (20.01)
Trend Symmetry		3.59 (2.65)	27.96 (21.12) [a]	17.44 (20.33)

The 95% CI *p*-value was considered significant if $p < 0.016$ ($p = 0.05/3$ after Bonferroni correction). *The symbol* [a] *denotes statistically significant differences with respect to control group.*

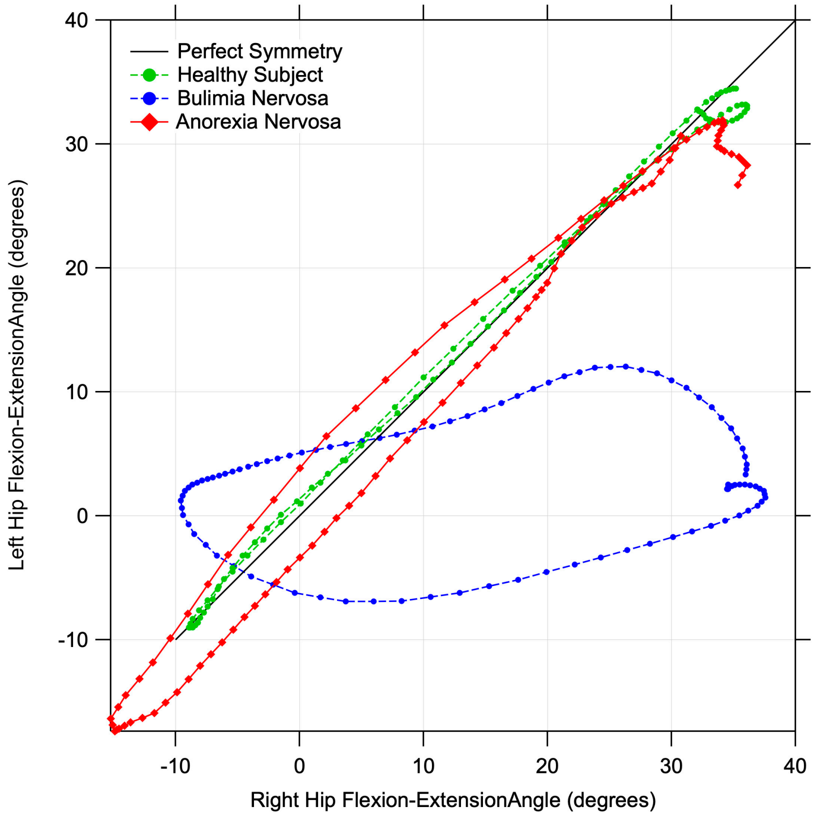

Figure 3. Examples of hip–hip cyclograms. The unaffected individual (green curve) is characterized by a very small area with an inclination close to the 45° line (which indicates perfect inter-limb symmetry). The individual with anorexia nervosa is characterized by a larger cyclogram's area but still relatively well-oriented. The individual with bulimia nervosa exhibits a very large cyclogram with a high orientation angle, thus indicating a very poor inter-limb symmetry.

4. Discussion

The aim of this study was to investigate the presence of inter-limb asymmetries during gait in female individuals with AN and BN and to compare the results with respect to a group of unaffected individuals using cyclogram features.

First, it should be mentioned that spatio-temporal parameters of people with EDs are significantly different from those of healthy controls; this is consistent with the existing literature. Individuals with EDs exhibit slower walking, in particular in the AN individuals, as well as a longer duration of double support phase compared with healthy weight individuals, as reported in a previous study [21]. As walking speed decreases, the duration of the double support phase increases and yields stability alterations [47]. According to the reported results, the double support phase duration appears to be more than doubled in both EDs with respect to controls, a fact that suggests the adoption of a strategy to pursue stability versus an increased postural instability caused by their conditions. Stability is usually connected to the ability to control the center of mass with respect to the base of the support [22], and since during the double support phase both feet are in contact with the ground, they can both be used to correct deviations and improve gait control [47]. According to what was reported by Fontana et al. [22], individuals with AN and BN exhibit reduced postural stability with respect to healthy individuals. The reasons for such instability can be either linked to psychological or physical factors, like weight fluctuations and loss of lean mass affecting the musculoskeletal system in both EDs. With respect to psychopathological aspects, it should not be forgotten that anxiety and the fear of losing control may also contribute to reduced postural control and stability [48–50]. Since humans are naturally able to modify the duration of the double support phase by modulating their speed and an increase in the double support phase increases stability, a motor strategy involving slow and controlled walking may be the easiest method to improve stability itself and thus reduce the risk of instability and falls.

With respect to symmetry, the cyclogram analysis suggests the presence of a well-defined trend characterized by altered symmetry in individuals with BN, whose features were found to be systematically higher than the healthy controls for hip, knee, and ankle. Although no significant differences were found in those with AN with respect to the other groups, a consistent trend of abnormal symmetry can be observed. To the best of our knowledge, no previous studies specifically investigated inter-limb symmetry of lower limbs during gait in individuals with a specifically diagnosed ED, and for this reason, there are no available data for direct comparison. However, previous studies that investigated gait smoothness in underweight populations using the harmonic ratio (HR), a parameter associated with step-by-step symmetry [51], showed similar results. HR in the medio-lateral direction was significantly lower in both underweight children [52] and elderly adults [4] with respect to healthy weight controls. This lack of symmetry, which is present in both AN and BN, might be representative of a reduced gait balance and is probably connected to the musculoskeletal alterations occurring due to malnutrition and weight fluctuations. Muscle weakness, together with unbalanced caloric intake, may be the cause of unpaired postural control and gait instability in patients with EDs [21,22].

Although gait asymmetries are also present in AN, those with BN exhibit the highest alterations in terms of symmetry during gait. Individuals with BN are prone to sudden and relevant body weight fluctuations, altering the fat/lean mass ratio and thus the musculoskeletal system, also leading to the possible onset of neuropathies due to unbalanced nutrition and purging cycles [22]. In this context, it can be hypothesized that changes in terms of gait symmetry and postural control might be more linked to body weight fluctuations rather than to BMI absolute values, as previously reported by Fontana et al. [22]. Overall, the findings of the present study suggest that evaluating inter-limb symmetry over the entire gait cycle may provide novel and valuable insights into the motor control impairments linked to EDs, thus supporting clinicians in determining the optimal rehabilitation path aimed at improving stability and motor control, optimizing energy costs during walking, and reducing, for instance, the risk of falls.

However, there are some limitations that should be considered. Firstly, the reduced number of participants limits, to some extent, the strength of the statistical results. However, in these pathological states, large experimental samples are difficult to collect because traditional gait analysis also requires that the patient wears minimal clothing, which has been shown to cause anxiety in these individuals as they are characterized by body dissatisfaction and misperception of body size [53]. Secondly, the different mean ages between groups should also be taken into account. Although there is evidence that BMI can influence mobility [54], it should also be noted that age can impact the biomechanical characteristics of the tissues [55,56] and affect body morphometry, especially between fertile and non-fertile age women [57]. However, the age difference did not seem to substantially influence the observed outcomes for the considered motor task.

Another limitation may be linked to the choice of assessing gait symmetry only in female individuals with EDs. Although EDs have been reported to be likely to occur in females [58], recent data have shown that their prevalence in men was previously underestimated and that the rates of EDs in males are increasing, without differences in terms of clinical severity with respect to females [7,59–61]. Due to the intrinsic physical differences between males and females, it could be interesting to also evaluate how musculoskeletal alterations due to EDs may impact gait symmetry and postural control in males. In addition, it should be noted that since biomechanical alterations of gait in individuals with EDs are influenced by a multitude of interconnected factors, it is difficult to understand the specific mechanisms behind gait changes. As more studies are conducted, our understanding of these interactions and their impact on gait in AN and BN will continue to develop.

5. Conclusions

This study assessed inter-limb symmetry in individuals with two different EDs through bilateral cyclograms' features, and it represents the first study focusing on inter-limb asymmetry using such a method in individuals with EDs. In this study, the cyclogram analysis suggests the presence of an altered gait symmetry in individuals with BN; even if not significant, this can also be observed in those with AN with a consistent trend of abnormal symmetry. This study warrants continued research to enhance the best characterization of walking strategies in EDs by applying innovative procedures to improve descriptions of the functional limitations during the walking of these patients. Further research could be conducted on this theme using other approaches, such as intra-limb coordination, in order to investigate different aspects of gait. Intra-limb coordination may reveal different patterns and categories of walking impairment in pathological subjects, uncovering the mechanisms of lower-limb motor control [62].

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