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Changes in the symmetry of the stabilization function of lower limbs in geriatric women versus younger females

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Changes in the symmetry of the stabilization function of lower limbs in geriatric women versus younger females

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A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
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F Literature Search
G Funds Collection

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abstract

Background: The overall purpose of this study is to define differences in the symmetry of stabilizing function of lower limbs in geriatric women compared to younger females.

Material and methods: The study evaluated 30 female seniors (aged 82.9 ±6.1), 39 female university students (aged 23.3 ±0.4) and 33 girls (aged 7.4 ±0.3). Stability was evaluated using a stabilographic platform CQ Stab (Electronic System), with the subject standing with eyes open. Anova Kruskal-Wallis test and Wilcoxon test were used for the analysis.

Results: The average percentage differences in limb loading (LLA) show a slight, not exceeding 2.5% asymmetry in the distribution of body weight. There was no statistically significant intergroup variation in this range. In extreme age groups asymmetry of indicators of the movement of the center of foot pressure (SPML MVML) was observed.

Conclusions: The shift in asymmetry of mass distribution towards the right lower limb (non-predominant) observed in the elderly women might point to tendencies for greater involvement of the limb which is less affected by the ageing processes. This, however, needs further investigation. The asymmetry of activity in the lower limbs in the stabilization function in elderly people needs to be offset through exercises improving somatosensory mechanisms of balance control.

Key words: body balance, body mass distribution, symmetry index, feminine gender.

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INTRODUCTION

Maintaining postural balance in humans represents an effect of active synergy between the motor system and numerous perceptive, control and regulation functions which are performed at different levels of the nervous system. This process has a character of dynamic adjustments to environmental conditions [1]. Therefore, it remains in close relationship with evolutionary and involutionary developmental changes of the body during ontogenesis [2, 3]. Differentiation in the efficiency of balance mechanisms is caused by the processes of development of the central and peripheral nervous system, receptors, as well as the muscles which are the effectors for steering impulses. Therefore, at each stage of life they are characterized by varying effectiveness and efficiency. Elderly people are prone to a decrease in stability, which is one of the main predictors of falls. Asymmetry in the distribution of body weight increasing with age is a factor reducing postural stability in older people [4].

Asymmetry of stabilization functions in the limbs in free standing position can be considered as differentiation of the center of pressure for each limb and limb load asymmetry. In the stabilographic image, in the sagittal plane, the course of the center of foot pressure on the ground (COP) is highly consistent with its total resultant for both the right and the left limb. However, in the frontal plane, the recorded profiles of the COP for individual limbs largely differ from each other and do not show phase relationships with the profile of the resultant COP for both feet. Furthermore, relationships between displacements of COP and distribution of the body mass, including displacements of more loaded limb were found. This shows that the dominant control over COP in mediolateral displacement is performed by the loading/unloading mechanisms as a result of activity of adductors and abductors of the hip joint rather than control of the muscles of the ankle joint [5, 6]. This behavior leads to asymmetry in loading the limb and COP displacements in the mediolateral direction [7, 8, 9]. The study shows that higher asymmetry of distribution of body mass is accompanied by increased sway in the anteroposterior direction [7, 9, 10]. Genthon and Rougier [8] found that in the case of asymmetry of mass distribution, amplitude of COP displacements increases under both feet, both in the mediolateral and anteroposterior directions, with stronger displacements observed in the mediolateral direction. Anker et al. [7] indicate that under the conditions of visual support this effect is less substantial in the unloaded foot. The increase in load asymmetry of lower limbs increases postural instability through reducing the efficiency of loading/unloading mechanisms and increases the compensation moments of the ankle joint. In conditions of visual feedback, the authors found a strong dependence of the stability on LLA. The increase in asymmetry of mass distribution caused a linear increase in the rate of COP displacement in the mediolateral direction, higher under the loaded lower limb, which is more active in the process of stability control.

The main purpose of this work is to determine the changes in the symmetry of the stabilization function of lower limbs in geriatric women versus younger females. The interpretation of the results might represent indication for specific forms of compensatory activities in the elderly people, mainly oriented at improvement in safety and the quality of living.

MATERIAL AND METHODS

The examinations involved 30 senior female residents of L.A. Helc nursing home in Krakow (mean age $\bar{x}$ = 82.9 ±6.1 years), 39 female students of Collegium Medicum of the Jagiellonian University in Krakow (mean age $\bar{x}$ = 23.3 ±0.4 years) and 33 girls from Primary School No. 2 in Krakow, Poland (mean age $\bar{x}$ =7.4 ±0.3 years). Selection of the research groups was purposive. The inclusion criteria were: dominating right hand and leg (determined on the basis of *Waterloo Handedness and Footedness Questionnaire – Revised* [11], physical fitness that allowed for walking without orthopedic equipment (i.e. walking canes, crutches, walkers), ability to take a standing position on the stabilographic platform independently, psychical status that allowed for participation in the study and following verbal instructions, a written informed consent to participate in the study (in the case of children, parents or legal guardians' consent). The study excluded persons after brain incidents, with hemiplegia and those who took medicines that might affect balance.

The examinations were approved by the directors of the related institutions and the acceptance of the Ethical Review Board of Rzeszow University (No. 11/02/2013) was obtained. Procedures were carried out in accordance with Helsinki Declaration. Each study participant was informed of the aim and method of the study.

Stabilographic measurements were performed using the two-platform posturograph CQ Stab (manufactured by Electronic System). The device allowed simultaneous recording of the vertical center of pressure position of forces in each foot. Data from 6 sensors (3 in each plate of the platform) were recorded. Sampling totaled 200 Hz per sensor. The disks of the platform were properly leveled, and their surfaces positioned to form a single plane. The test consisted in measuring the body stability in a relaxed standing position, with eyes open. The stance width of the lower limbs and the feet angle were natural. A fixation point was placed 1 meter away opposite the subject. After entering the platform, the subject stood still trying to keep her eyes on the point of reference. The proper measurement was preceded by 30-second "training" to stabilize the balance. Next, the test lasting 30 seconds was recorded. In order to avoid any kind of learning or fatigue effect only one valid trial in each condition was then retained in the analysis [12, 13].

During the test the researcher was behind the tested person. In order to preserve the integrity of the research process, all the tests were carried out in the morning, using the same measuring instruments operated by the authors. The measurements were taken in the gym, in conditions which ensure the isolation of acoustic stimuli that could interfere with postural reflexes during the study. Women were wearing their gymnastic suits without shoes.

The statistical analyzes included the distribution ratios of body weight, which were calculated using the platform software according to the formula:

$$LLA(t) = (MP(t)-ML(t)-)/(ML(t)+MP(t)) \cdot 100\%$$

where:
LLA – limb load asymmetry,
ML(t) – mass measured on the left platform at the instant t,
MP(t) – mass measured on the right platform at the instant t,
t – time.

The following indicators of stability were analyzed (for each lower limb):

- SPAP – statokinesiogram path length on the OY axis (the sagittal plane, anteroposterior direction, AP), in mm;
- SPML – statokinesiogram path length on the OX axis (the frontal plane, mediolateral direction, ML), in mm;
- MVAP – mean velocity of COP displacement on the OY axis, in mm/s;
- MVML – mean velocity of COP displacement on the OX axis, in mm/s;
- SA – sway area delimited by the COP point, in mm^2;
- MF – mean frequency of COP displacements, in Hz.

Symmetry ratios for individual parameters describing the movement of the center of foot pressure were calculated for each subject according to the formula:

$$SI = \frac{R - L}{\frac{R + L}{2}} \times 100$$

where:
R – value for the right lower limb
L – value for the left lower limb [14].

On the basis of the gathered data the following descriptive statistics parameters were calculated: arithmetical mean values ($\bar{x}$), standard deviations (SD) and medians (Me). The normality of distribution of particular characteristics was verified by means of the Shapiro-Wilk test. Due to the lack of compliance of the tested variables with normal distribution, non-parametric tests were used. In order to check whether there is a statistically significant intergroup difference in the distribution of body mass indices and indicators of symmetry (SI), the Anova Kruskal-Wallis test along with two-sided post-hoc test with Bonferroni correction for each compared pair was used. To assess the significance of differences between the results obtained for the lower right and left limb, the Wilcoxon test was used. Results were considered statistically significant if the probability level of the test was lower than the predetermined level α = 0.05. In this study, STATISTICA StatSoft 10.0 was used to process the statistical test results.

RESULTS

Data in Table 1 indicate no statistically significant differences between the groups in terms of preferred loading of specific lower limb. The results only suggest that in free standing position the left lower limb is more often loaded by girls (LLA = 2.48) and the right one by senior females (LLA = 2.27).

Table 1. Comparison of body mass distribution values (ANOVA Kruskal-Wallis rank test)

Indicator	Girls (n = 33)		Mature women (n = 39)		Seniors (n = 30)		*p*
	$\bar{x}$ ±SD	Me	$\bar{x}$ ±SD	Me	$\bar{x}$ ±SD	Me	
LLA	-2.48 ±9.92	-3.00	1.44 ±7.66	1.00	2.27 ±11.81	2.00	0.152

In girls, the average indicators of stability in the mediolateral direction (SPML, MVML) and the mean frequency of COP displacement achieve higher values in the left lower limb. The values of stability related to the path length of statokinesiogram and the average speed of COP displacement are close, about 18% each. In the case of the mean frequency of COP displacement, the symmetry index is equal to SI = -38.26%, which is the highest value in relation to other indicators. The results indicate the symmetry of loading on the lower limbs in anteroposterior sways and a lack of symmetry in mediolateral sways. Higher values of stability in the mediolateral direction observed in the case of the left lower limb, suggest a tendency to use this limb as support, while the right one has the manipulation function (Table 2). It is worth noting that the average values of stability in girls are much higher compared to mature women (Tables 2–3).

Table 2. Comparison of stability indicators in the right and left lower limb (Wilcoxon test) and values of symmetry indices (SI) in girls

Indicator	Right lower limb		Left lower limb		*Z*	*p*	SI
	$\overline{x}$ ±SD	Me	$\overline{x}$ ±SD	Me			
SPAP	423.45 ±153.72	35.09	413.42 ±79.25	403.00	1.51	0.214	1.74
SPML	298.12 ±91.15	277.00	352.33 ±73.94	349.00	2.00	0.000*	-18.57
MVAP	14.11 ±5.12	12.00	13.78 ±2.64	13.40	1.51	0.221	1.76
MVML	9.93 ±3.04	9.00	11.75 ±2.46	11.60	1.84	0.000*	-18.71
SA	537.36 ±349.61	443.00	433.75 ±273.38	392.00	0.29	0.367	13.11
MF	1.10 ±0.56	0.94	1.87 ±1.24	1.68	0.29	0.002*	-38.26

*$p < 0.05$

Average values of stability indicators achieve similar values for the left and right lower limb in the group of mature women. There was no statistically significant difference in this respect. Values of asymmetry indicators do not exceed 4% (Table 3).

Table 3. Comparison of stability indicators in right and left lower limb (Wilcoxon test) and values of symmetry indices (SI) in mature women

Indicator	Right lower limb		Left lower limb		*Z*	*p*	SI
	$\overline{x}$ ±SD	Me	$\overline{x}$ ±SD	Me			
SPAP	211.69 ±64.59	191.00	202.05 ±49.21	196.00	0.71	0.455	3.91
SPML	137.10 ±24.82	128.00	142.51 ±24.79	143.00	0.11	0.109	-3.79
MVAP	7.04 ±2.15	6.40	6.73 ±1.63	6.50	0.92	0.488	3.82
MVML	4.56 ±0.82	4.30	4.75 ±0.82	4.80	0.15	0.117	-3.80
SA	173.00 ±126.01	135.00	168.23 ±106.55	156.00	0.40	0.383	2.65
MF	0.76 ±0.34	0.71	0.80 ±0.37	0.72	0.21	0.372	-2.59

*$p < 0.05$

In seniors, same as in girls, the statokinesiogram path length and the average speed of COP displacement in the mediolateral direction were significantly higher in the left lower limb, as compared to mature women. Differences expressed in the symmetry index were almost similar and oscillated around 26% for the discussed parameters. Average indicators of stability in seniors, particularly in the anteroposterior direction, had higher values than in mature women. Within the oldest group, we also noticed an increase in the diversity of results expressed in the increase in the measures of dispersion (SD). This indicates deterioration in stability with age (Table 4).

Table 4. Comparison of stability indicators in right and left lower limb (Wilcoxon test) and values of symmetry indices (SI) in seniors

Indicator	Right lower limb		Left lower limb		Z	p	SI
	$\bar{x}$ ±SD	Me	$\bar{x}$ ±SD	Me			
SPAP	313.36 ±146.45	283.50	309.86 ±166.94	276.50	1.47	0.749	2.42
SPML	145.23 ±44.99	139.50	189.56 ±51.90	186.00	0.38	0.000*	-25.84
MVAP	10.44 ±4.88	9.45	10.33 ±5.57	9.25	1.45	0.742	2.37
MVML	4.84 ±1.50	4.65	6.32 ±1.73	6.20	0.34	0.000*	-25.88
SA	206.56 ±120.60	193.00	266.03 ±178.63	197.00	0.13	0.175	-15.22
MF	0.78 ±0.30	0.75	0.91 ±0.39	0.94	1.68	0.084	-11.55

*$p < 0.05$

Data in Table 5 show statistically significant intergroup differences in the symmetry index values defined for the statokinesiogram path length and the average speed of COP point moving in the mediolateral direction. The biggest differences are seen in the group of girls and mature women, and between mature women and seniors. Intergroup variation was also found in the symmetry index for the mean frequency of COP displacement. In mature women SI values are significantly lower than in girls. This indicates a higher level of stability of mature women.

Table 5. Comparison of values of symmetry indices (SI) for the analyzed parameters of stability (Anova Kruskal-Wallis rank test)

Indicator	Girls (n = 33)	Mature women (n = 39)	Seniors (n = 30)	p	Post-hoc
	$\bar{x}$	$\bar{x}$	$\bar{x}$		
SPAP	-1.74	3.91	2.42	0.269	-
SPML	-18.57	-3.79	-25.84	0.001*	G-MW; MW-S
MVAP	-1.76	3.82	2.37	0.279	-
MVML	-18.71	-3.80	-25.88	0.001*	G-MW; MW-S
SA	13.11	2.65	-15.22	0.219	-
MF	-38.26	-2.59	-11.55	0.043*	G-MW

G-MW: girls-mature women; MW-S: mature women-seniors; G-S: girls-seniors
*$p < 0.05$

DISCUSSION

The results obtained in the study show that asymmetry of mass distribution, which is a manifestation of the limb load strategy in the frontal plane does not exceed 2.5% in free standing position and does not significantly differ between the groups.

Limb load asymmetry values suggest stronger loading of the left lower limb in the youngest girls and the right limb in the oldest group. The direction of predominance of the limbs remains an open question in the literature. Gutnik et al. [15] observed the asymmetry in body mass distribution towards the right lower limb where more load was applied for most of the time. Explanation for this fact was greater body mass distributed on the right body side (mass of upper limb, muscles of the right body side, mineral density of the bone) [15, 16, 17].

Other authors also found the advantage of the left or the lack of noticeable predominance of either of the limbs [9, 18, 19]. Blaszczyk et al. [9] noticed that limb load asymmetry in the group of young and older women similarly concerns both left and right lower limb.

The results obtained in our study correspond to the data presented by Heese et al. [20], who examined subjects aged 19 to 40 and found no correlations between limb predominance and the preferred side of body mass distribution. The fact of a different direction of limb load asymmetry in the oldest subjects might suggest the aging-related tendency for more frequent use of the limb which is the least affected by the ageing processes as a support limb [21].

From the biomechanical point of view, maximum stability should be achieved by a system under conditions of symmetry. This status is conducive to using the strategies of ankle and hip joint, whereas at senior age, these strategies are not entirely successful. Thus, it is presumed that asymmetry of limb loading creates optimum conditions for application of lunge strategy, i.e. performing a step with less loaded foot [9, 18].

In our study, poorly marked asymmetry in the distribution of body weight (LLA) is accompanied by a significant difference in the values of stability indicators of each limb. This mainly applies to the statokinesiogram path length and the mean velocity of COP displacement in the mediolateral direction. Strong asymmetry of the indicators of stability was found in the group of girls and seniors. Asymmetry observed in the group of 7-year-old girls suggests the advanced in this age process of shaping preferences in lower limbs for the manipulation and stabilization functions [22]. This substantial asymmetry of COP displacement in limbs in the youngest subjects and poor asymmetry in female university students suggest the gradual development of the symmetrical optimum in ontogenesis, which is typical of a mature body. In university students, asymmetry of body mass distribution and stability indices between the limbs is the least noticeable. This demonstrates that the symmetry of body mass distribution from the biomechanical standpoint should be an optimal state for sustaining body balance and can be realized in subjects with a broad stability margin [5, 7]. In other words, high effectiveness of balance control mechanisms results in the lowest values of stability indicators asymmetry in this group and the body is ready for equally quick reactions in any direction. According to Blaszczyk et al. [18], increased asymmetry in the elderly people is an effect of using the strategies that consist in preventing body destabilization through performing a lounge with the predominant limb (less loaded). In light of the findings of this study, it is difficult to support the thesis proposed by the authors due to the lack of significant differences in limb load asymmetry between the studied age categories. On the other hand, higher activity of the stabilization function of one limb might suggest such patterns. The stability control assessment allows mapping out suitable implementation of preventive treatments and rehabilitation. Analysis of the changes in the symmetry of the lower limbs stabilizing function in geriatric women against the younger generation of females indicates a need to include specific forms of compensatory activities in training programs for seniors which would comprise exercises aimed at improving the proprioceptive function and coordination (yoga, Tai Chi, gentle exercise), increase in muscle strength and endurance (resistance exercises using elastic bands, swimming), improvement in balance (exercises on unstable surface, such as ball, sensory pillow). The use of gear increases the attractiveness of exercises and makes it possible to modify the position thus preventing the monotony and enhancing motivation. Such forms of physical activity practiced systematically can contribute to mitigating the adverse changes associated with age. Maintaining the optimal – in relation to age – level of functionality can help to reduce the risk of falls improving the psychophysical condition and raising the quality of seniors' life.

CONCLUSIONS

Limb load asymmetry in free standing position does not deepen in the process of ontogenetic development. It is not the same as the lack of asymmetry of indices of COP displacements for either of the limbs, which are significantly different in the groups of elderly people, adults and children. This asymmetry mainly concerns displacements in the mediolateral direction performed by muscles stabilizing the ankle joint. Girls and seniors show a noticeable functional predominance of the left limb (not necessarily more loaded) in stabilization of the body posture. The results of the study suggest that asymmetry in children is a manifestation of natural evolution processes in children and, on the other hand, it is the result of involution changes in elderly people ensuring human postural stability. They suggest a need for leveraging differences, especially in the elderly people, through exercises that maintain proprioceptive functions at a high level.

REFERENCES

[1] Puszczalowska-Lizis E, Bujas P, Omorczyk J. Postural stability in women in the eighth and ninth decades of life. Acta Bioeng Biomech. 2016;18(3):115-121.

[2] Gmiat A, Mieszkowski J, Prusik K, et al. Changes in pro-inflammatory markers and leucine concentrations in response to Nordic Walking training combined with vitamin D supplementation in elderly women. Biogerontology. 2017;18(4):535-548. https://doi.org/10.1007/s10522-017-9694-8

[3] Wilczynski J, Pedrycz A, Mucha D, Ambrozy T, Mucha D. Body posture, postural stability, and metabolic age in patients with Parkinson's disease. Biomed Res Int. 2017;2017:3975417. https://doi.org/10.1155/2017/3975417

[4] Blaszczyk J, Michalski A. Ageing and postural stability. Stud Phys Culture Tourism. 2006;13:11-14.

[5] Winter DA, Prince F, Frank JS, Powel C, Zabjek KF. Unified theory regarding the A/P and M/L balance in quiet stance. J Neurophysiol. 1996;75:2334-2343. https://doi.org/10.1152/jn.1996.75.6.2334

[6] Gage WH, Winter DA, Frank JS, Adkin AL. Kinematic and kinetic validity of the inverted pendulum model in quiet standing. Gait and Posture. 2004;19(2):124-132. https://doi.org/10.1016/S0966-6362(03)00037-7

[7] Anker LC, Weerdesteyn VW, Van Nes IJ, Nienhuis B, Straatman B, Geurts ACH. The relation between postural stability and weight distribution in healthy subjects. Gait Posture. 2008;27(3):471-477. https://doi.org/10.1016/j.gaitpost.2007.06.002

[8] Genthon N, Rougier P. Influence of an asymmetrical body weight distribution on the control of undisturbed upright stance. J Biomech. 2004;38(10):2037-2049. https://doi.org/10.1016/j.jbiomech.2004.09.024

[9] Blaszczyk JW, Prince F, Raiche M, Hèrbert R. Effect of ageing and vision on limb load asymmetry during quiet stance. J Biomech. 2000;33(10):1243-1248. https://doi.org/10.1016/S0021-9290(00)00097-X

[10] Sackley CM, Baguley B, Gent S, Hodgson P. The use of balance performance monitor in the treatment of weight-bearing and weight-transference problems after stroke. Physiotherapy. 1992;78(12):907-913. https://doi.org/10.1016/S0031-9406(10)60498-1

[11] Perrin P, Deviterne D, Hegel F, Perrot C. Judo, better than dance, develops sensorimotor adaptabilities involved in balance control. Gait Posture. 2002;15(2):187-194. https://doi.org/10.1016/S0966-6362(01)00149-7

[12] Tarantola J, Nardone A, Tacchini E, Schieppati M. Human stance stability improves with the repetition of the task: effect of foot position and visual condition. Neurosci Lett. 1997;228(2):75-78. https://doi.org/10.1016/S0304-3940(97)00370-4

[13] Chiari L, Rocchi L, Cappello A. Stabilometric parameters are affected by anthropometry and foot placement. Clin Biomech. 2002;17(9-10):666-677. https://doi.org/10.1016/S0268-0033(02)00107-9

[14] Herzog W, Nigg BM, Read LJ, Olsson E. Asymmetries in ground reaction force patterns in normal human gait. Med Sci Sport Exerc. 1989;21(1):110-114. https://doi.org/10.1249/00005768-198902000-00020

[15] Gutnik B, Leaver J, Standen C, Longley C. Inferred influence of human lateral profile on limb load asymmetry during a quiet standing balance test. Acta Med Okayama. 2008;62(3):175-84.

[16] Slemenda CW, Miller JZ, Hui SL, Reister TK, Johnston CC. Role of physical activity in the development of skeletal mass in children. J Bone Miner Res. 1991;11(6):1227-1233. https://doi.org/10.1002/jbmr.5650061113

[17] Matava MJ, Freehill AK, Grutzner S, Shannon W. Limb dominance as a potential etiologic factor in noncontact anterior cruciate ligament tears. J Knee Surg. 2002;15:11-16.

[18] Blaszczyk JW, Lowe DL, Hansen PD. Ranges of postural stability and their changes in the elderly. Gait Posture. 1994;2(1):11-17. https://doi.org/10.1016/0966-6362(94)90012-4

[19] Sobera M. Charakterystyka procesu utrzymywania równowagi ciała u dzieci w wieku 2-7 lat. [Characteristic of maintaining body balance process in children aged 2-7 years]. Wrocław: AWF; 2010. Polish.

[20] Heese S, Schauer M, Jahnke MT. Standing-up in healthy subjects: symmetry of weight distribution and lateral displacement of the center of mass as related to limb dominance. Gait Posture. 1996;4(4): 287-292. https://doi.org/10.1016/0966-6362(95)01051-3

[21] Prieto TE, Myklebust JB, Myklebust BM. Characterization and modeling of postural steadiness in the elderly: A review. IEEE T Rehabil Eng. 1993;1(1):26-34. https://doi.org/10.1109/86.242405

[22] Gentry V, Gabbard C. Foot-preference behavior. A developmental perspective. J Gen Psychol. 1995;122(1):37-45. https://doi.org/10.1080/00221309.1995.9921220

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