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PATTERN OF GAIT ANALYSIS IN WOMEN – CASE STUDY

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Abstract

Our study deals with 3D kinematic analysis of human gait which is based on case study of women walking. The purpose of this research was using 3D kinematic analysis and obtaining very precise kinematic characteristics in chosen key phases of human gait. Specially we were interested in center of gravity movement. Adult healthy woman in age of 45 years was videotaped by 2 synchronised high speed cameras and analysed by biomechanists. Tested person has mostly sedentary style of life but she likes cycling and swimming activities. Step frequency was set by pace maker (frequency 90 steps/min), walking in amount of four steps was realised in laboratory conditions, on wooden ground and using sport shoes.

1. Introduction

Human gait is the way of locomotion which is characterized by differences in body movement patterns (especially limbs), overall velocity, velocities of body segments, overall acceleration, acceleration of body segments, forces, kinetic and potential energy cycles, and changes in the contact with the surface. Our study deals with 3D kinematic analysis of human gait which is based on case study of women walking. Also the other autors deal with analysis and idetification of different types of gait. Research team Maurer et al., 2014 used foot kinematics and pedobarographyphy because they can be used to identify 3 types of midfoot break (MFB), which represents a foot deformity (Pronated MFB, Supinated MFB and Flat foot MFB). Spánik et al., (2012) studied kinematic structure of selected dance figure, Psalman, (2007) and Psalman, & Zvonar, (2007) were using 3D biomechanical analysis for diagnostics of dynamic balance abilities, Arus, (2013)

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were using 3D biomechanical analysis in martial arts. General view into biomechanics of musculoskeletal applies Zatsiorski, (2012).

2. Materials and Methods

Adult healthy woman in age of 45 years was videotaped by 2 synchronised high speed cameras and analysed by biomechanists. Tested person has mostly sedentary style of life but she likes cycling and swimming activities. Step frequency was set by pace maker (frequency 90 steps/min), walking in amount of four steps was realised in laboratory conditions, on wooden ground and using sport shoes.

With the help of 3D kinematic analysis and Simi motion software seventeen body segments were recorded (head, left shoulder, right shoulder, left elbow, right elbow, left wrist, right wrist, left hip, right hip, left knee, right knee, left ankle, right ankle, left forefoot, right forefoot, left heel, right heel). We focused on 5 key time moments during tested walking: step time, swing time, stance time, single support time, double support time and 3 length parameters: step length, stride length, support base. Support base was measured as middle support (not lateral or medial) which represents the length difference between both ankle bones in side direction during double support phase.

Specially we were interested in center of gravity movement. Center of gravity was calculated by Simi Motion software and Gubitz model was applied. For all body segments some other characteristics like velocity, acceleration and angles were fulfiled. Based on mentioned above, expert evaluation of tested gait is available. Standardization of the testing equipment was made by authors Duvac & Kasa, (2005).

3. Results and Discussions

There are gender differences in human gait: females walk with lesser step width and more pelvic movement. Gait analysis generally takes gender into consideration. Females walking with hip sway, and males walking with swagger in shoulder generally have more physical attractiveness. All outputs are in numerical and graphical forms. (*Figure 1)*

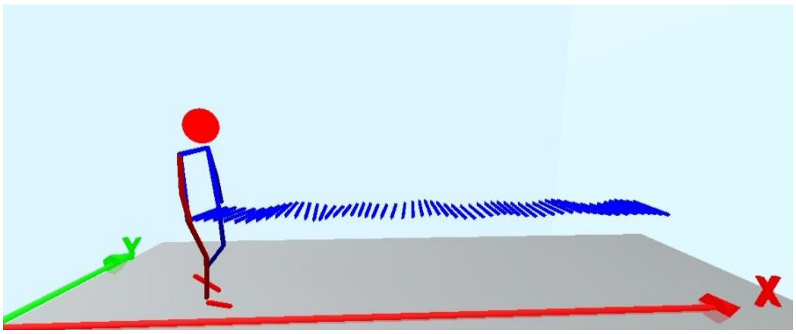


Figure 1 *Trajectory of hips axis (side view)*

Movement of hips has personal variability in range 77 - 91 degrees and plus 12 and minus 12 degrees at side and top views. Lateral center of gravity (COG) movement is realized from 27,7 to 35 cm (*Figure 2*) which shows difference more than 8 cm but for normal range we can consider the values between 31 and 34 cm. The higher differences confirm that women walking is more active in hips area which is caused by higher atraction/atractivity or there also can be some small side inbalances where above mentioned extrems were achieved/recognized.

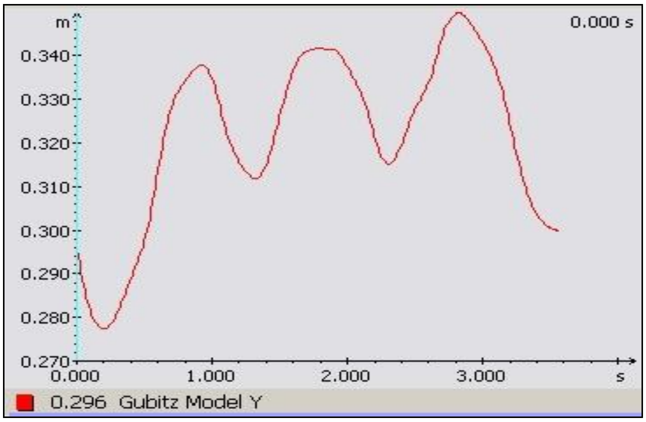
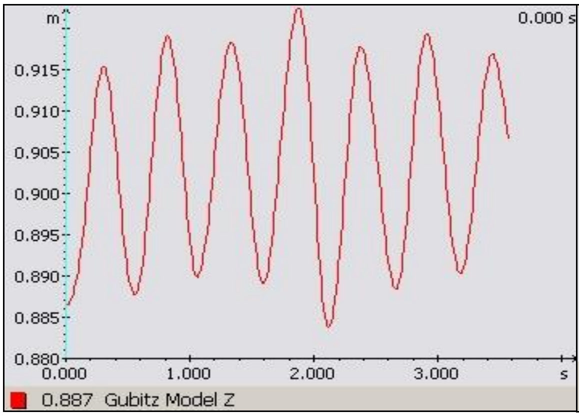


Figure 2 *Lateral movement of center of gravity*

COG movement in vertical direction, oscillating from 88,8 up to 92,0 cm, with minimal value of 88,3 cm which represents the lowest body position and maximum with 92,5 cm in the most upright position (*Figure 3,4*). Here we can see that another 0,5 cm are added and more or less upright position depends on stability of body during the walking.



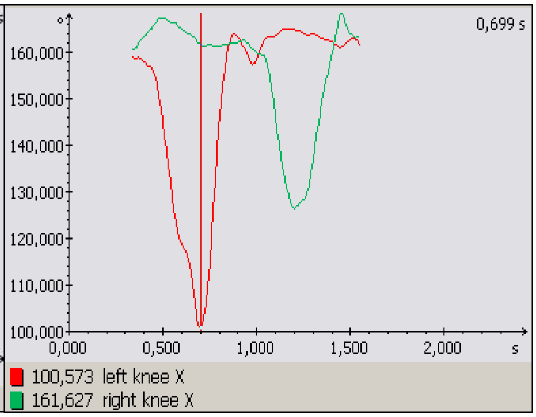


Figure 3 *Vertical movement of center of gravity*

Figure 4 *Different knee flexions - woman and her maximal flexion of left and right knee*

There is significant different between flexion of both knees – about 26 degrees. Difference can be caused by one of these possibilities:

a) muscle disbalance between quadriceps and biceps femoris;
b) shortening of femoris muscles.

More precise analyses can be done with help of deeper muscle monitoring by Electromyography. (*Figure 5)*

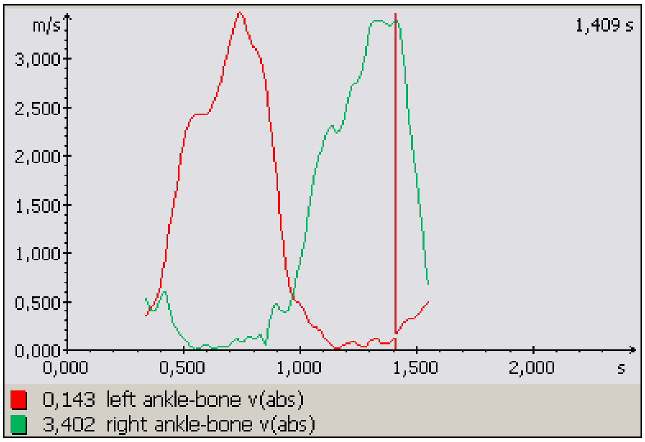


Figure 5 *Maximal velocity of the right ankle bone*

This picture shows maximal velocity of the right ankle bone in time 1,409 s which looks like the flat peak, keeping maximal velocity for longer time than it was realized by left ankle bone (sharp peak, not able to keep velocity). These results proofs nearly similar velocity values, which is normal, but on the other hand we can see different duration during maximal velocity value. Caused difference can be done by different lateral dynamic stability, or by former injuries, or abnormal body posture. (*Figure 6)*

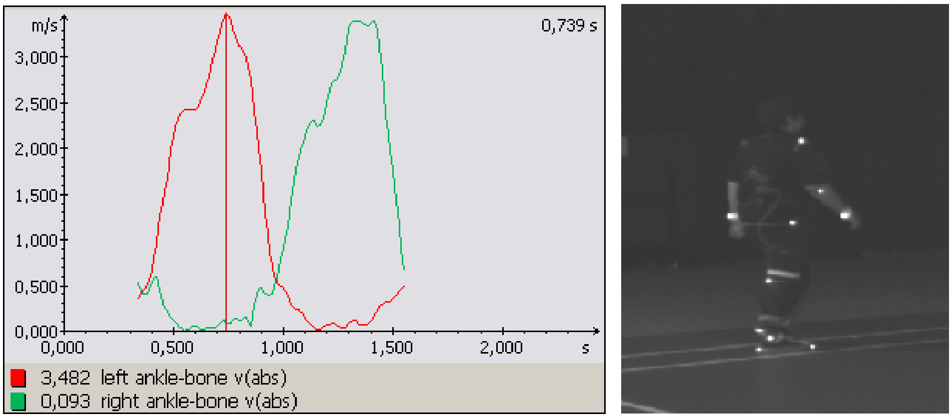


Figure 6 *Maximal velocity of the left ankle bone*

Phase where is the flexion changed into the extension in left knee / the edge between early and late swing is exactly in time 1,199 s. In this time is the left ankle bone much more forward comparing to the right one. Length difference is 27,8 cm proves the walking instability during swing phases. Also, this woman is not able to recognize and feel the movement edge between early and late swings. (*Figure 7a, b)*

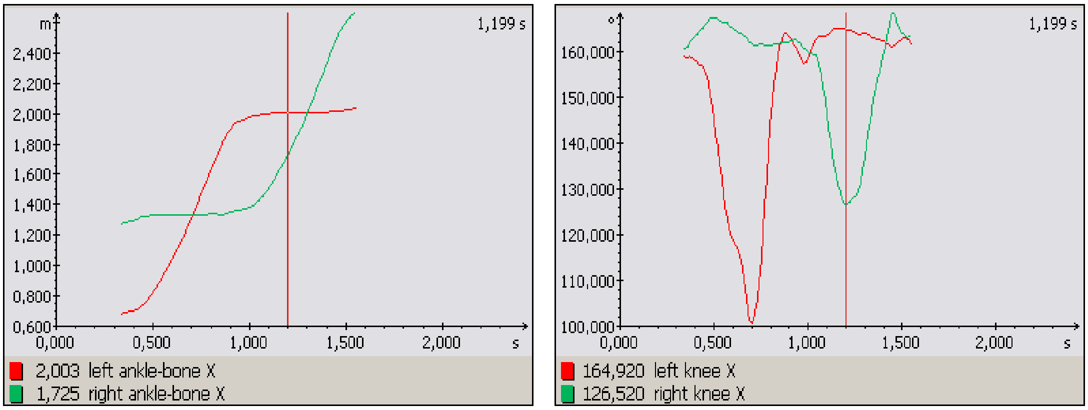


Figure 7a, b *Phase of flexion and extension*

Phase where is the flexion changed into the extension in left knee / the edge between early and late swing is exactly in time 0,699 s. In this time both legs have the same position because of the length achieved also the same values (legs crossing from side view). (*Figure 8)*

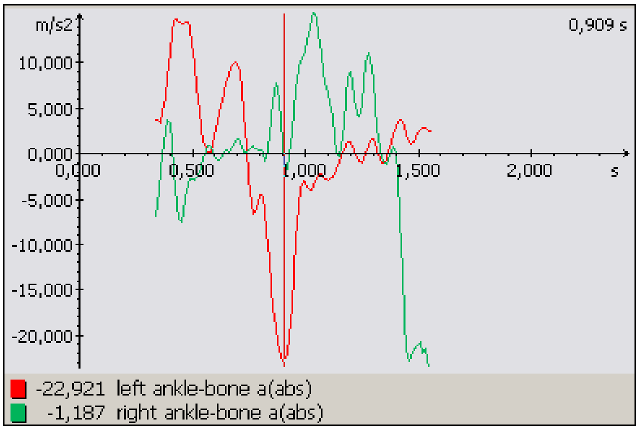


Figure 8 *Acceleration and deceleration of both legs*

On this picture we can clearly see that process of deceleration during normal walking is bigger than process of acceleration. Maximal values of decelerations are -22,921 m/s^2 for the left ankle bone and -23,575 m/s^2 but on the other hand, accelerations had maximal values only 14,899 m/s^2 and 15,542 m/s^2.

Head movement is quite stable and regular as it is seen in the *figure 9* which shows length in horizontal direction. But the next figures (*Figure 10a, 10b*) are more impressive and we can see that movement of the head is stable because its velocity varies only in range from 1,008 m/s to 1,491 m/s, mostly oscillating around 1,200 m/s. The same we can say about accelerations – from -5,111 m/s^2 to 7,949 m/s^2.

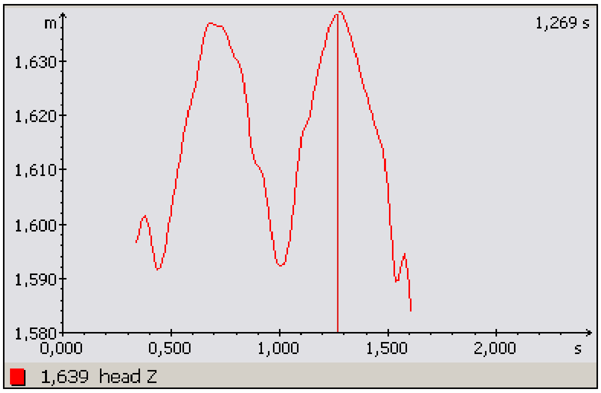


Figure 9 *Vertical head movement*

Height of the head moved from 1,510 to 1,556 m (dif 0,046 m) and center of gravity had differences from 0,884m to 0,922m (dif 0,038 m). Many outputs of velocity (from 1,23 to 1,63 m/s) and acceleration (from -2,66 to +2,52 m/s^2) parameters were achieved. All these results and their quality were confirmed by experts as well. Head movement has its maximum in 1,639 m and minimum 1,589 m which represents the difference of 5cm. Shaking head is confirming the aggressive type of walking.

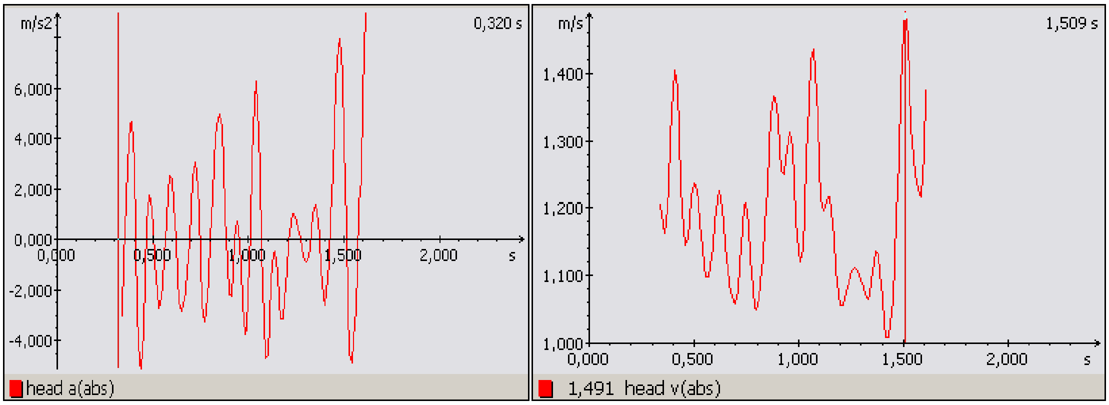


Figure 10a, 10b *Vertical head velocity and acceleration*

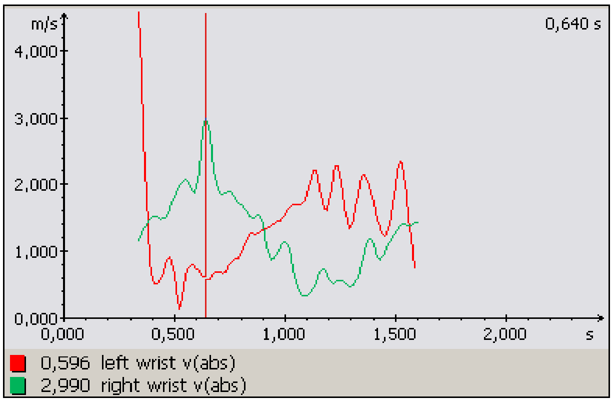


Figure 11 *Activity of upper extremities*

Activities of the wrists are opposite but the process looks be completely different. While the left wrist has several velocity peaks, right wrist has just only one in time 0,640s. (*Figure 11)*

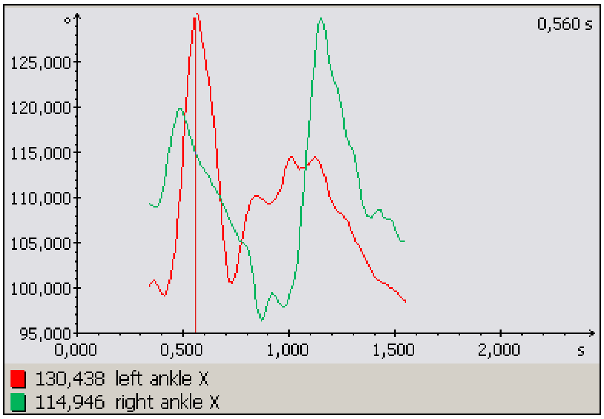


Figure 12 *Angle in both ankle joints*

Range in working angles appears to be interesting because there are similar maximal values of both ankles (130 versus 129 degrees). But comparing minimums, the difference is 7 degrees and all together it represents the total difference between the ankles 8 degrees (difference of the right ankle is 9 and difference of the left ankle is 17 degrees). (*Figure 12)*

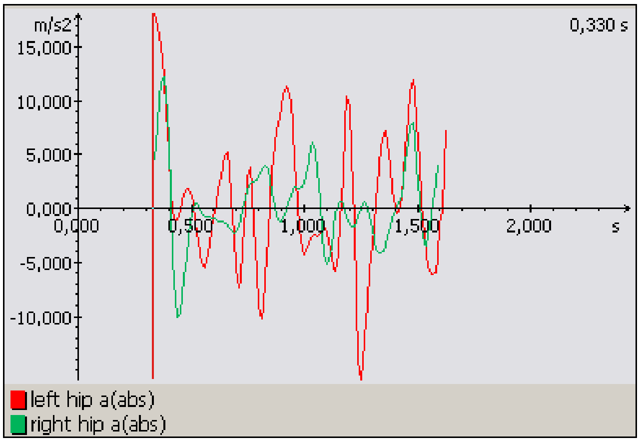


Figure 13 *Hip acceleration*

More active is the left hip with higher oscillating around zero level, the right hip is more stable and without as big accelerations and decelerations as we could see at left hip. (*Figure 13)*

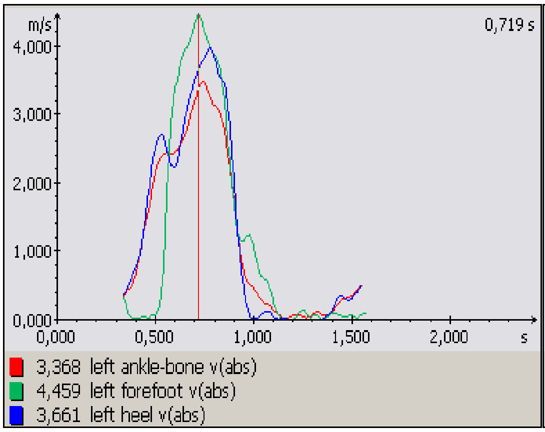


Figure 14 *Trajectory and velocity of selected left side points*

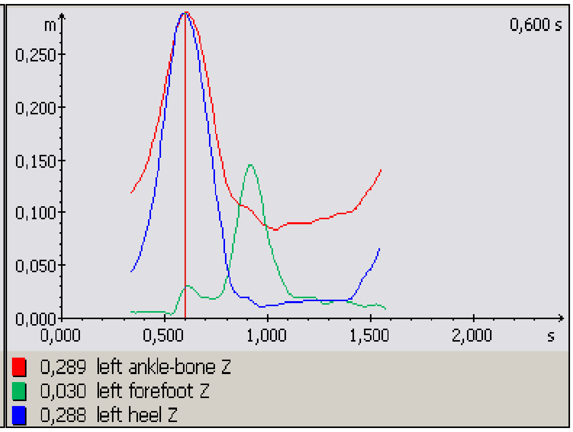


Figure 15 *Trajectory and velocity of selected right side points*

Left anklebone and left heel do nearly similar raising (28,9 and 28,8 cm), while left forefoot moves in lower range (14,5 cm). Velocities with their maximal values are the highest in case of forefoot, than in heel and finally, the slowest is ankle bone. (*Figure 14,15)*

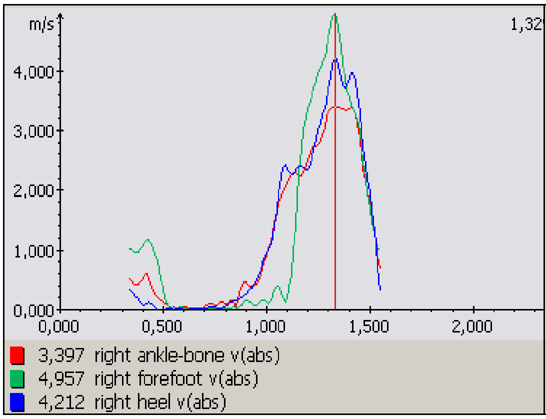


Figure 16 *Trajectory and velocity of selected left side points - secvential*

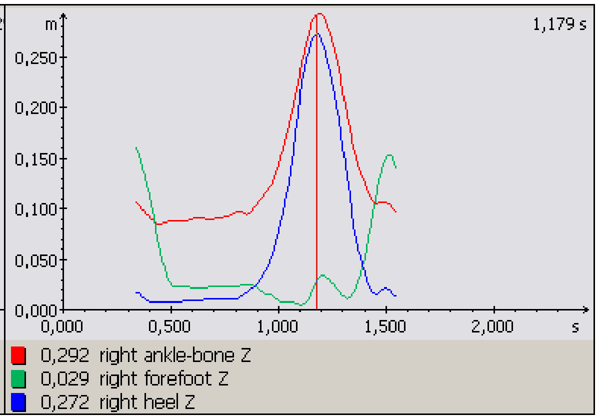


Figure 17 *Trajectory and velocity of selected right side points- secvential*

Right anklebone and right heel achieved their maximal values which differs in 2 cm (29,2 cm resp. 27,2 cm) approximately at the same time moment (1,179 s). (**Figure 17** Little bit later (1,509 s) appeared the maximal value of forefoot, which was 15,2 cm. Time 1,329 shows the maximal velocity of right forefoot with the value reaching nearly 5 m/s (4,957 m/s). **Figure 16**

We can see how is the velocity lost in the left ankle bone during the support phase. The lowest but the most constant velocities were obtained by both hips. These are the locations which are very close to the center of gravity and they should be slower than other distal parts of human body.

4. Conclusions

Human gait analysis can be done very precisely and sufficiently by using 3D kinematic analysis. This study brings also specific characteristics of woman walking (gait type and gait abnormalities) which support subjective expert evaluations of healthy walking. These evauations are mostly charecterized by movement and its range in foloving body segments (ankles, knees, hips, arms, elbows, wrists and head) and center of gravity.

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