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REHABILITATION WITH NORDIC POLES OR CRUTCHES?

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Abstract: *Human evolution took millions of years, within them our body was adapted according to global environmental changes. Over of years, we reached the upright position, and with it came problems. As specialists say, it was our desire to reach high, and thus today we have ache at the lower spine, and the ankle joints are overloaded. Except of that the modern life style, and the mechanization of the works, is sending us to a sedentary work by control of a production process by the computer. Thus, most of the day we seat, and similarly a part of the population that is affected by their medical problem, as arthritis, muscle weakness, and the fear of falling due to compromised stability. To improve their life by socializing, to be independent, and physically active, they are asking abou types of supports, and suitability for them. To help, and provide the answer we started the walk project, and identification of cons and pros of supports.*

Keywords: Gait, Aid support, Posture.

1. Introduction

Evolution affected the anatomy and posture of our ancestors. With the anatomy changed, even the mechanics of motion was adjusted. Apes advantage of four limbs allowed to reduce the stress at joints. The earliest hominid with the evidence of bipedalism is the 4.4-million-year-old Ardipithecus ramidus (Wayman E, 2012). Bipedalism separated the first hominids from the four-legged apes, and brought many changes. Since that, the total weight of the body is supported only by two lower limbs, which results to a higher load at joints. Along with the anatomical changes, the body posture has also changed, and the mechanical force transmission system, that can overload parts of the body as such the lumbar spine. Modern lifestyle reduces unwillingly our physical activity, which simultaneously weakens the muscular system, that is anticipated mainly at a sedentary work. Therefore, the core muscle, connecting the axial and appendicular skeleton, might be weaken, and effect the posture, which can lead to pains at the low back (LBP). Observing different postures, and the respective movements of the individuals, uncovers unique gait of each subject, that can be affected by internal and external factors. The study of gait can be seen from perspective of anatomy, physiology, sociology, environmental, psychological, or biomechanical. Our study was oriented into the biomechanical area, with observation, and analysis of a clinically important measurement. There is a very small number of papers dealing with the comparison between different types of walking support for elderly to increase their stability, rehabilitation, etc. The aim of this work was to identify the effect of crutches, and Nordic poles (NP) during the walk, and identify the pros and cons of each type of the support. Our voluntary subject was a woman between 60-65 of age, diagnosed with bilateral osteoarthritis.

2. Gait and its measurable data

The word gait, represents the manner or style of movement generated by limbs. There is no average person but there is a gross similarity in our manner of walking. Smooth walking requires proper posture, when the subject decreases vertical and lateral movements with controlled pelvic rotation and tilt,

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including the lateral displacement of the pelvis, control foot, ankle, and knee motion, and its flexion after heel-strike in stance phase. The gait cycle of the human movement is defined as time interval between two successive occurrences of one of the events within the sequence of walking. The one cycle is identified from a foot strike to second foot strike of the same leg. Gait parameters are divided into three groups: a) spatial-temporal parameters - gait speed, and stride length of the pace performance can be easily characterized by comparison with the walking standard, established on recording of large amount of subjects.

b) temporal parameters - cadence, step, stride, stance, and swing time

c) spatial parameters – step, and stride length

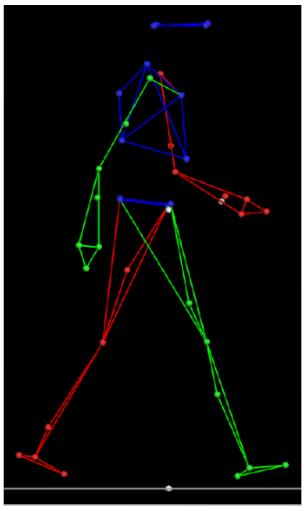

Fig. 1: Match-stick model.

2.1 Recording the trajectories

To be able to evaluate the impact of crutches, and NP for the subject's walk, the motion was recorded using VICON system with eight infrared cameras of frequency 1000 Hz, and two force-plates to record the reaction forces of the subject's foot. The reflexive markers were fixed on the subject's body to mark each segment of the limb, other parts of the whole body, and record as well the posture of the subject during the walk. The subject, ready for the recording, was asked to provide three times the walk without any support, three times walking with crutches, and three times with NP. After the nine recordings were done, then the reflective markers at the joints, and segments, were labeled according to the standard, while using abbreviation, and the VICON match-stick model on Fig. 1 was created. Once the recorded data, in the format '.c3d' and '.csv', were associated to each respective marker, then all packages were processed.

2.2 Force plates and forces

The VICON system, recording the kinematics data of walk, and the inbuilt force-plate system, were synchronized to record the reaction forces generated by the pushing foot as shown in Fig. 2. The reaction force between the force-plate and a foot is used for further computation of the loads acting at the joints of the lower limb. The muscular forces can be recorded using a surface Electromyography (sEMG) system that can be synchronized with the cameras, and force-plates. Use of the sEMG is limited only to surface muscles to avoid a cross-talk between the surface muscle and the muscle passing under it. To complete the comparison between the two types of support sticks, we need to obtain forces transferred to the ground floor. This was not possible in our case as the walking path in our laboratory is narrow, and the force-plates are very closed to each other so the pole's forces and the reaction forces couldn't be recorded simultaneously.

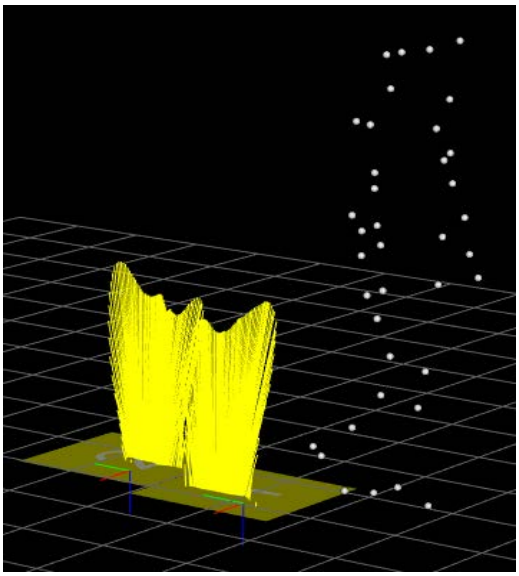

Fig. 2: Pedotti diagram of the ground reaction forces.

2.3 Data processing

A zero-phase filtering method is commonly used with application of the filtering the signal twice. The choice of cut-off frequency (*fc*) at 5-6 Hz for gait analysis is imperative as to avoid the cut-off of wanted signal (Rácz, K., Kiss, R. M. 2021), or of maximum 10 Hz. Record of ground reaction forces (GRF) had to be cropped for clear diagram of the respected forces from fist and second force-plate, to obtain the diagram of force components.

2.4 Walking aids

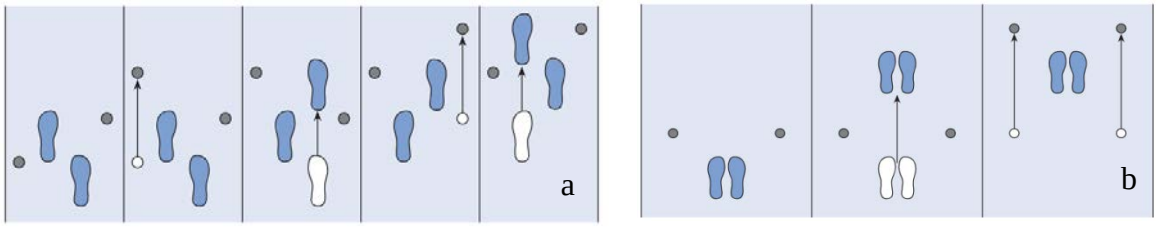

Fig. 3: a) Nordic poles with four point walk; and b) crutches with three point walk.

The two types of the aids differ not only in the design that is unusual at NP, compared to classical crutches, thus forcing the user to hold the NP in his hand at perpendicular position to the pole, while the crutches have a handle at perpendicular position to the rod. Therefore, the load transfer via sticks is different, that resulted to a change of walking characteristic. Our project is considering only users able to walk, but their problem is the stability, or users who need to reduce a load on the limb.

3. Results

Presently we have only data of the volunteer's walks with bilateral osteoarthritis, who used both types of walking aid. The anthropometric data of the subject were uploaded to VICON system. The data of the total length of the walk were cropped using Mokka SW to visualize the recorded walk. To obtain a one gait cycle, the .c3d recording frames of frequency 1000 Hz were selected base on the strike of the left leg at the begining, and second time at the end of the cycle. Then the scale in frames was converted into a percentage scale of the walk, for possibility to compare each recording. To evaluate the spatial-temporal parameters, the neccessary frames of the gait cycle were converted into time scale, and parameters were computed for each recording. The results were compared with the common values of normal gait. To evaluate the cadence, the recording in format '.c3d' was running with Mokka SW, counting the number of steps during the whole path, and number of recorded frames during the walk. Then the cadence (steps/time) was calculated. In the normal walk of a healthy person the left and right step have same

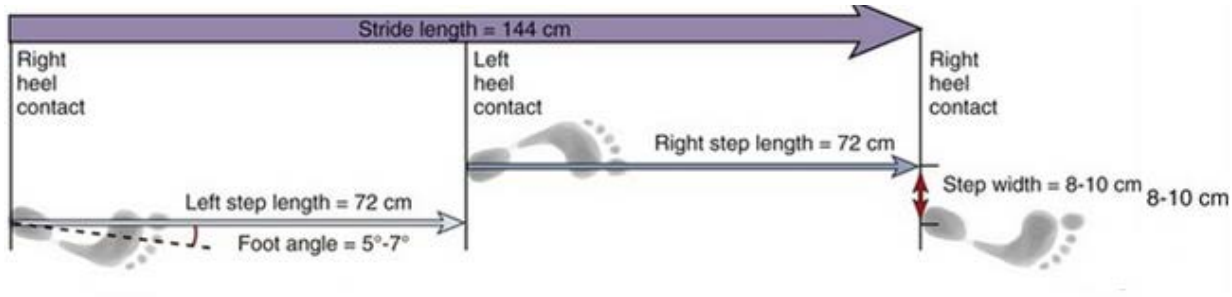

Fig. 4: Spatial descriptors of gait.

length, thus the stride length can be considered as a double step length. To assessed some of the spatial-temporal parameters, the kinematics parameters such as speed, and acceleration must be computed. To obtain these parameters, we can use another source of recorded data from Excel.csv files. The speed and acceleration were computed based on the data marker position, provided in the components *x*, *y*, *z*, of the respective trajectory vector, and applying the first and second derivative.

$$\boldsymbol{r} = x\boldsymbol{i} + y\boldsymbol{j} + z\boldsymbol{k} \quad (1)$$

$$\boldsymbol{v} = \frac{d\boldsymbol{r}}{dt} = \frac{d}{dt}(\dot{x}\boldsymbol{i}) + \frac{d}{dt}(\dot{y}\boldsymbol{j}) + \frac{d}{dt}(\dot{z}\boldsymbol{k}) \quad (2)$$

$$\boldsymbol{a} = \frac{d\boldsymbol{v}}{dt} = (\ddot{x}\boldsymbol{i}) + (\ddot{y}\boldsymbol{j}) + (\ddot{z}\boldsymbol{k}) \quad (3)$$

Comparing the cadence of our subject with the healthy female performance, is showing big difference. The lowest frequency of steps, 58steps/min. was reached while using crutches, the cadence of 62steps/min. during the walk with NP, and 75steps/min. at the free walk without any support. It was observed that the subject had some issues to keep stability at unsupported walk, during the walk with NP the walk was more stabilized and similar to normal style of walk, while with crutches the walk looks

uncomfortable and stiff. The subject's body posture improved, and the almost natural direct walk was kept during the two supported walks.

Tab. 1: Gait spatial-temporal parametr.

Cadence by normal female walk			
age	18 - 49	50 - 64	65 - 80
cadence [steps/min]	98 - 138	97 - 137	96 - 136

leg of the two has an urgent need to be respectively treated. Comparing the force value of the right foot shows the lowest force of 406 N using crutches, 441 N for NP, and unsupported walk of 498 N. The left leg generated GRF of 464 N with crutches, 470 N by NP, and 495 N without support.

Our project didn't reach the target, but provided other information, that can identify same pros or cons of the supports. Further work is planned to find the way how the force transferred through the stick can be recorded, and synchronized with VICON system experiment.

4. Conclusion

Research of walk has a long history, that delivered number of characteristics of a healthy subject that serve as indicator of subject's problem, and directs the analysis into the expected area.. Comparing the GRF of the left and right leg indicate, which

Fig. 5: Ground reaction forces of walk with crutches.

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