Gait parameters when walking with or without rollator on different surface characteristics - a pilot study among healthy individuals

Eva Ekvall Hansson (eva.ekvall-hansson@med.lu.se)
Lunds Universitet https://orcid.org/0000-0001-7552-6486
Yara Akar
Lund University Faculty of Medicine: Lunds universitet Medicinska fakulteten
Tingting Liu
Lunds University Faculty of Medicine: Lunds universitet Medicinska fakulteten
Cong Wang
Lund University Faculty of Medicine: Lunds universitet Medicinska fakulteten
Agneta Malmgren Fänge
Lund University Faculty of Medicine: Lunds universitet Medicinska fakulteten

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Abstract

Objectives: Gait parameters can measure risks of falling and mortality and identify early stages of frailty. The use of walking aid changes gait parameters. To identify what a dysfunctional gait is, one must be able to define what a normal gait is both with and without a walking aid. The aim of this study was to describe differences in gait parameters among healthy adults when walking on different surfaces and under different conditions, with and without a rollator.

Results: Ten healthy participants walked first without and then with a rollator upslope, downslope and on flat surface, on bitumen and gravel respectively. Step length, walking speed and sideway deviation was measured using an inertial measurement unit. Walking up a slope using a rollator generated the longest step length and walking down a slope using a rollator the shortest. Fastest walking speed was used when walking up a slope with rollator and slowest when walking down a slope with rollator. Sideway deviation was highest when walking down a slope and lowest when walking on gravel, both without rollator. Data from this study provides valuable knowledge regarding gait parameters among healthy individuals, useful for future clinical research relevant for rehabilitation and public health.

Introduction

Mobility is a prerequisite for the vast majority of everyday activities, and being able to move around outdoors contributes to societal participation (1, 2), and is known to reduce depression and social stigma (3). Increasing age is associated with physical activity limitations due to illness, injury or general age-related health decline (4). Walking is an easily accessible way of performing physical activity. To be able to walk as fast as required to gain health benefits, walking outdoors is usually necessary. Walking outdoors is however a complex task that places demand on e.g., muscle strength, balance, and cognition. Difficulties to walk may be caused by possible transportation barriers, walking distance, having to manage walking in traffic with time limits (crossing the street on signals), maneuvering among people, bicycles or other objects, difficult terrains, and the rapid changes of the environment (5). Therefore, gait parameters included in walking can be of interest. Gait parameters are often used to measure risks of falling, and mortality, and identify early stages of frailty (6). Thus, it must be understood how gait can be associated with these clinical features, to come up with preventive measures.

A reduction in gait characterizations can indicate a probable need of using a walking aid (7). There are different types of walking aids that help in reducing dependency and increasing functionality in the environment (7), with the rollator as one common walking-aid (8). The use of a rollator increases in particular gait velocity and step length (9). Older persons who use rollator, especially women, are highly overrepresented in single accidents in traffic (10).

For a clinician to successfully identify what a dysfunctional gait is, first, one must be able to readily define what a normal gait is both with and without a walking aid. Thus, after defining a normal gait with its general population-based parameters, the clinician knows what to expect and what to look for (6).

Knowledge concerning gait parameters among healthy persons can also be useful when planning rehabilitation focusing on regaining activity and enable participation in the society.

Thus, the aim of this study was to describe differences in gait parameters among healthy adults when walking on different surfaces and under different conditions, with and without a rollator.

Materials And Methods

The study was an experimental, cross-sectional pilot study. Participants was recruited among students and staff at Lund University, using the following inclusion criteria: 18 years or older; consider themselves healthy; and without known health conditions that could impact their mobility. No other inclusion or exclusion criteria was use. 10 participants were included; seven women and three men, aged 23–62 years (Median 35 years).

Measures

Gait was measured with a nine-axis Inertial Measurement Unit (IMU), worn on the right thigh. The IMU includes an accelerometer, magnetometer, and gyroscope that can detect and measure movement patterns when changing body positions in the frontal, sagittal and mediolateral planes and analyze gait. The IMU also comprises a GPS and a clock. IMU:s is a practical and portable way of collecting this type of data (11) and can be used for analyzing a range of components of movements (12). The IMU used in this project was custom-built, with project-specific measurements such as sideways deviation, but made use of the proprietary Snubblometer library from Infonomy AB for step detection and gait classification (www.infonomy.com). The Snubblometer has shown good validity and reliability for measuring postural sway (13), for detecting a near-fall (14) and good ability to identify future fallers (15). IMU's has shown excellent validity and reliability in terms of gait analysis, however, a strict protocol is recommended (16, 17).

Gait was measured using three parameters: step length, walking speed and sideway deviation. Step length is defined as step in cm, which is a half gait cycle (right heel strike to left heel strike), and walking speed in m/s. The project in question was considered exploratory, and therefore the sensor's frame of reference was used to calculate sideways deviation as a catch-all for both translational movement and rotation in the mediolateral direction. These two movement types are closely related, as a significant sideways step always corresponds to an outward or inward rotation of the thigh. In sideway deviation, the discretized (at 50 Hz) time-integral of the absolute value of the apparent acceleration along the Z-axis (aligned with the mediolateral axis of the body) was calculated for each step and divided by the total step duration to calculate an arithmetic mean of the absolute value of the Z-acceleration during the step. This measure functions as a flag for steps comprising a high degree of sideways movement, and because it is calculated by the absolute value, it will register sideways movement regardless of whether the movement is towards the right, towards the left, or whether the acceleration during a particular step is monodirectional or bidirectional (positive acceleration followed by negative acceleration, or vice versa, which would cancel each other out if the integral was not of the absolute value). The measure was described as “sideways deviation” for simplicity, as it is analogous to a deviation from the center line of the gait movement, but as the accelerometer measures apparent acceleration rather than true acceleration, a high value can also be caused by a large shift in sideways inclination, without much translational movement.

The gait parameters were measured during walk under two different conditions: with and without the use of a four wheeled rollator. In addition, gait was measured for each condition on different surface characteristics: up-slope, down-slope, bitumen, and gravel paths. All up-slope and down-slope sections were paved with bitumen, while all gravel paths were flat.

Procedure

The outdoor walk consisted of a lap that partly went in parallel to a bicycle route, and several streets were crossed, including tramrails and traffic lights. Two observants noted the exact time when the environmental condition changed, for example the beginning and end of a gravel part of the lap. Each lap was walked twice, first without rollator, and secondly with rollator. The lap was in total 2.5 km long, with a gravel part of approx. 600 m in the first half the lap. The slope was 100 m long, with an inclination of 1:40. Each lap took 30–45 minutes to finish. The participants had a convenience break between the two laps, approx. 5–10 minutes.

Data were collected during February-March 2021. Thus, the weather conditions varied from dry to wet conditions, with a temperature between 0–15 degrees Celsius.

Data analysis and statistics

IBM SPSS version 25 was used for statistical analyses. The data generated by the IMU were recorded each second and analyzed according to the different environmental characteristics in the outdoor walk, with and without rollator. Since not all variables were normally distributed and sample size was small, both mean (M) and standard deviation (SD) as well as median (Md) and min-max values were used. Since repeated measures was applied, an analysis of variance was performed, using related samples two-way Friedmans analysis of ranks, and Bonferroni for adjusting. Since sample size was small, the analysis was performed for walking with and without rollator separately, as well as the different gait parameters separately. In addition, the Wilcoxon Signed Rank test was used to calculate differences between walking on different surfaces, up a slope and down a slope, and with or without rollator. A p-value ≤ 0.05 was used for determining statistical significance (18).

Calculating with minimal clinical statistical difference of 0.1 m/sec in walking speed (19), with a standard difference of 0.15 m/sec (20) and statistical significance of 0.05, a sample size in a full-scale study was set to 70 participants. In this pilot-study, sample size was estimated to about 15% of the full-scale study, that is 10 participants.

Results

Both the longest and shortest steps were taken while walking with a rollator, with the longest step length used when walking upslope (M = 52.44 cm, Md = 54.87 cm) and shortest step length was used when walking downslope (M = 43.77 cm, Md = 41.04). The highest and lowest walking speed was also identified when the rollator was used. The highest speed was measured when walking upslope with rollator (M = 0.98 m/s, Md = 1.07 m/s) and the lowest speed when walking downslope with rollator (M = 0.84 m/s, Md = 0.75 m/s). Highest sideway deviation was found when walking downslope, without rollator (M = 0.19 g, Md = 0.18 g) and lowest sideway deviation was found when walking on gravel without rollator (M = 0.17 g, Md = 0.16 g). Mean values and SD for the different variables when walking in the different terrains, with and without rollator are displayed in Table 1.

Table 1
Descriptive statistics of gait parameters when walking on different surfaces and during different conditions. N = 10.

	Step length /cm		**Walking speed m/s**		**Sideway deviation /g**	
Walking conditions	**Mean (SD)**	**Median (min-max)***	**Mean (SD)**	**Median (min-max)**	**Mean (SD)**	**Median (min-max)**
Walk upslope	51.27(7.88)	51.20(41.13–60.73)	0.96 (0.15)	0.97 (0.75–1.17)	0.17 (0.03)	0.17 (0.12–0.23)
Walk downslope	48.97 (8.36)	50.83 (38.00-59.22)	0.95 (0.19)	0.95 (0.70–1.19)	0.19 (0.03)	0.18 (0.14–0.25)
Walk on gravel	50.11 (7.17)	48.42 (38.60-60.36)	0.94 (0.15)	0.94 (0.70–1.11)	0.17 (0.03)	0.16 (0.12–0.22)
Walk on bitumen	50.18 (8.04)	51.01 (37.67–62.22)	0.96 (0.16)	0.99 (0.69–1.17)	0.18 (0.03)	0.17 (0.12–0.22)
Rollator walk upslope	52.44 (9.47)	54.87 (40.25–62.84)	0.98 (0.22)	1.07 (0.68–1.25)	0.17 (0.03)	0.17 (0.12–0.23)
Rollator walk downslope	43.77 (10.01)	41.04 (33.22–61.10)	0.84 (0.25)	0.75 (0.59–1.29)	0.18 (0.04)	0.18 (0.13–0.25)
Rollator walk on gravel	51.31 (8.33)	51.15 (36.43–60.19)	0.95 (0.21)	0.92 (0.67–1.31)	0.17 (0.03)	0.18 (0.13–0.22)
Rollator walk on bitumen	46.82 (8.59)	45.36 (32.51–57.42)	0.89 (0.22)	0.85 (0.61–1.19)	0.17 (0.04)	0.17 (0.13–0.25)
*Since not all variables were normally distributed and the sample size is small, both mean and median values are shown.						

The analysis of variance when walking without a rollator revealed that significant differences were found in sideway deviation between walking on gravel and walking upslope ($p \leq 0.001$). The analysis of variance when walking with a rollator revealed significant differences in step length between walking downslope and walking on gravel ($p = 0.01$), walking upslope and walking downslope ($p \leq 0.001$) and walking on gravel and walking upslope ($p = 0.03$).

Two sample analysis revealed significant differences ($p = 0.01–0.02$) in step length were found between walking downslope with rollator and all the conditions when walking without a rollator. Differences ($p = 0.02–0.05$) in walking speed were found between walking down a slope with rollator and walking without a rollator upslope, walking down a slope and walking on bitumen. For sideways deviation, differences ($p = 0.03–0.05$) were found between walking down a slope without a rollator and rollator walk on gravel and walking with a rollator on bitumen.

Table 2

Differences in step length, walking speed and sideway deviation between walking with and without a rollator in the different walking conditions and surfaces, N=10.

	Walk upslope[1]	**Walk downslope**[1]	**Walk on gravel**[1]	**Walk on bitumen**[1]
Step length in cm				
Rollator walk upslope	1.17 (9.00) 0.56	3.47 (8.74) 0.14	2.34 (8.14) 0.29	2.26 (9.18) 0.39
Rollator walk downslope	7.50 (6.09) **0.01**	5.20 (5.44) **0.02**	6.33 (6.41) **0.02**	6.41 (6.00) **0.01**
Rollator walk on gravel	0.95 (6.85) 0.44	1.35 (4.24) 0.17	0.21 (5.49) 0.99	0.13 (5.13) 0.99
Rollator walk on bitumen	4.45 (0.09	2.15 (5.28) 0.24	3.29 (6.26) 0.11	3.36 (5.63) 0.11
Walking speed in m/s				
Rollator walk upslope	0.02 (0.17) 0.51	0.03 (0.18) 0.33	0.04 (0.17) 0.24	0.02 (0.17) 0.44
Rollator walk downslope	0.12 (0.15) **0.04**	0.11 (0.13) **0.02**	0.10 (0.17) 0.09	0.12 (0.15) **0.05**
Rollator walk on gravel	0.01 (0.15) 0.58	0.00 (0.18) 0.80	0.01 (0.15) 0.99	0.01 (0.13) 0.99
Rollator walk on bitumen	0.07 (0.15) 0.11	0.06 (0.13) 0.07	0.05 (0.16) 0.20	0.07 (0.14) 0.09
Sideway deviation/g*				
Rollator walk upslope	0.00 (0.02) 0.80	0.02 (0.03) 0.07	0.00 (0.02) 0.88	0.01 (0.01) 0.39
Rollator walk downslope	0.01 (0.02) 0.28	0.01 (0.02) 0.39	0.02 (0.03) 0.06	0.01 (0.02) 0.24
Rollator walk on gravel	0.00 (0.02) 0.72	0.01 (0.02) **0.03**	0.00 (0.02) 0.44	0.01 (0.01) 0.33
Rollator walk on bitumen	0.00 (0.03) 0.88	0.01 (0.02) **0.05**	0.01 (0.02) 0.24	0.00 (0.00) 0.96

Statistically significant p-values are displayed in bold.
[1]Mean diff (SD). P-value calculated by Wilcoxon signed ranked test.

*****g=gravitational acceleration

Conclusions

Step length, speed and sideway deviation during walking can differ depending on rollator use, walking surface and environmental characteristics, at least among healthy individuals. Walking with a rollator generated differences in gait parameters compared to walking without a rollator. Sideway deviation also differ prominently when walking without a rollator on different surfaces and under different conditions. The type of gait parameters used in this study can be easily measured using wearable devices, such as IMU:s.

Our findings provide valuable knowledge regarding gait parameters among healthy individuals, useful for future clinical research relevant for rehabilitation planning and evaluation. The findings are valuable for the design of pedestrian routes in urban areas to support physical activity and participation in the population.

Limitations

The study has several limitations. To be able to compare walking with or without a rollator, people who considered themselves healthy were enrolled in this study. This approach has been used before, since it is difficult, or even unethical, to ask persons who are dependent on a walking aid, to walk without it (21). Gait velocity and stride length have however been shown to differ between first time users of a different types of walking aid, such as rollators, crutches and three-wheeled walkers, and frequent users (9). These factors, together with the results from our study, can be useful when planning future research among people with disabilities.

Even if sufficient for the study design applied, the sample size was small (22, 23), which of course limits the ability to draw conclusions. We aimed to include a larger number of participants, however, due to the COVID-19 restrictions in Sweden, this was not possible. Instead, we extended the walk so that the loop included a large variety of different surfaces and environmental conditions. Thus, we managed to collect a large amount of data from each participant which increased the ability to draw some preliminary conclusions (24). Another limitation is that we used only one IMU to collect data for each participant. Using additional IMU:s is for example reliable for measuring trunk range of motion (25) and to detect anticipatory postural adjustments (26). However, we used the same lap in all walks, which increases reliability of the data collected.

In future research, the use of several IMU's can extend the type of data that can be collected in this type of experimental studies and thereby expand knowledge on which type of movements that are necessary for a person to manage to be able to walk outdoors. In this aspect, research regarding gait parameters among older people and people with disabilities is also important.

Abbreviations

IMU Inertial Measurement Unit

M Mean

SD Standard deviation

Md Median

Declarations

Ethics approval and consent to participate: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Swedish Ethical Review Authority (dnr 2020-00084). Participation in the study was voluntary and written informed consent was received before the start of the data collection. All data were de-identified and coded before data analysis and no individual data are displayed.

Consent for publication: Written informed consent has been obtained from the participants to publish this paper.

Conflicts of Interest: The authors declare no conflict of interest.

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Data Availability Statement: Data will be available upon reasonable request

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