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DOES AN ANATOMIC REFERENCE MARKER SERVE TO ESTIMATE HORIZONTAL CENTER OF MASS VELOCITY DURING GAIT?

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SUMMARY

The use of center of mass (CoM) kinematics information permits to perform several biomechanics analyses. One of the most common analyses is the average velocity during locomotion. When acquiring motion analysis data for determination of CoM position, a number of markers is required. Sometimes it takes several time for subject preparation as well as data analysis. When considering the interest only in quantify the horizontal velocity component during gait, it is possible that a single marker tracking might satisfactorily describe the horizontal velocity component of the CoM. Here we tested the use of single markers to describe the horizontal velocity of CoM during gait.

INTRODUCTION

Kinematics of the center of mass (CoM) is a reliable variable to quantify gait velocity during human locomotion. The information on CoM velocity permits to address several aspects of the human gait, including stability [1]. The CoM kinematics is often recorded from video based analyses that require a number of anatomical reference markers attached to the subject's body. According to literature, the calculation of CoM requires between 27 [2] and 40 [3] anatomical reference markers placed in the body, depending on the model and the instrument utilized. The necessity to attach several markers on many body segments involves long time for subject preparation. Additionally, it increases errors when working with video analysis and manual tracking.

For gait assessment aiming to quantify horizontal gait velocity, the use of a single reference marker that could correlate with the CoM horizontal velocity during gait can contribute to the faster subject's preparation and therefore shorten the experimental sessions. However, it is unclear whether a reference point can serve as a reliable measure to estimate CoM horizontal velocity during gait.

The aim of this study was to analyze whether an anatomic reference marker can serve to estimate CoM horizontal center velocity during gait.

METHODS

Ten healthy subjects (7 women and 3 men) volunteered to the study. They were aged 25.4 years (±5.23), body mass of 72.11 kg (±9.69) and height of 1.77 m (±0.05). They were requested to walk at freely chosen velocity in a pass way of 8 m in the laboratory. For the kinematic analysis, thirty-nine reference markers (14 mm diameter) were positioned in specific sites of the subject's body according to the Plug-in Gait Full Body Modelling (Vicon Motion Systems, Oxford, England). Kinematics data were acquired using a motion analysis system (Vicon Nexus, Vicon Motion Systems, Oxford, England) with 7 infra-red cameras operating at 100 Hz. Cameras were synchronized to the force data acquired at 1000 Hz using two force plates (OR6-6-2000, Advanced Mechanical Technology Inc., USA). Force plates were used to detected gait events. CoM position was calculated by the motion analysis system utilized considering the position of all the segments of the body and some anthropometric measures (body mass, height, ankle width, knee width, leg length, elbow width, hand thickness, shoulder offset and wrist width). Kinematics data were low pass filtered at 8 Hz - 4th order Butterworth filter.

Horizontal velocity was computed during one trial (two gait cycles) for each subject for CoM and for one marker from the head, two markers from the torso and one marker from the pelvis, which are described below. Marker 1 - head (positioned on the subject's left temple); Marker 2 - clavicle (positioned on the jugular notch where the clavicles meet the sternum); Marker 3 - pelvis (positioned on the left anterior superior iliac spine); and Marker 4 - sternum (positioned on the xiphoid process of the sternum). The segment masses and radii of gyration can be were approximated from published tables [4].

Data distribution was analyzed using Shapiro-Wilk test. Horizontal velocity was compared between CoM and the markers using Wilcoxon test. The correlation between CoM and the markers was verified using Spearman correlation test. The significance level considered was set at 0.05 for all tests.

RESULTS AND DISCUSSION

Table 1 presents the correlations between the CoM velocity and the other four markers. Marker 1 had significant correlation with the CoM in 17 of the 20 gait cycles included in the study. Marker 2 had significant correlation in 14 gait cycles. Marker 3 velocity had significant correlation with the CoM velocity in 8 gait cycles. And the Marker 4 had significant correlation in 11 gait cycles analyzed.

However, when observing the ρ value of the Spearman's correlations, it was possible observe that the velocity of the Marker 1 had moderate to strong correlations with the CoM velocity in eight of the twelve cycles. The Marker 2 (clavicle) had moderate to strong correlations for the same variable in 5 gait cycles. The marker positioned on the pelvis (Marker 3) had just in 2 gait cycles had moderate to strong correlations. And for Marker 4 it occurred just in 3 gait cycles.

Wilcoxon suggested similar values between the CoM and the markers for the most of the frames, except in 6 gait cycles for Marker 1 and one cycle for each of the other markers.

CONCLUSIONS

When considering a single marker to represent the subject horizontal velocity during walking, there are some evident limitations. A marker in the head of the subject can be assumed as with satisfactory correlation to the CoM horizontal velocity.

REFERENCES

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Table 1: Correlation coefficients (ρ) identified for each of the markers considered in this study. All the markers' correlations are in respect to the CoM velocity.

Gait Cycle	Marker 1	Marker 2	Marker 3	Marker 4
1	ρ=0.272*; P=0.004	ρ=-0.446*; P=0.000	ρ=-0.585*; P=0.000	ρ=-0.479*; P=0.000
2	ρ=0.000; P=0.999	ρ=-0.574*; P=0.000	ρ=-0.497*; P=0.000	ρ=-0.511*; P=0.000
3	ρ=0.774*; P=0.000	ρ=0.510*; P=0.000	ρ=0.138; P=0.156	ρ=0.403*; P=0.000
4	ρ=0.807*; P=0.000	ρ=0.626*; P=0.000	ρ=0.281*; P=0.003	ρ=0.528*; P=0.000
5	ρ=-0.156; P=0.083	ρ=-0.034; P=0.711	ρ=-0.288*; P=0.001	ρ=-0.092; P=0.308
6	ρ=-0.036; P=0.693	ρ=0.046; P=0.616	ρ=-0.124; P=0.170	ρ=-0.063; P=0.488
7	ρ=0.568*; P=0.000	ρ=0.290*; P=0.003	ρ=-0.224*; P=0.023	ρ=0.071; P=0.476
8	ρ=0.330*; P=0.001	ρ=0.346*; P=0.000	ρ=0.070; P=0.486	ρ=0.068; P=0.497
9	ρ=0.385*; P=0.000	ρ=-0.060; P=0.540	ρ=0.047; P=0.632	ρ=-0.090; P=0.357
10	ρ=0.480*; P=0.000	ρ=0.042; P=0.670	ρ=0.119; P=0.223	ρ=-0.085; P=0.384
11	ρ=0.382*; P=0.000	ρ=0.460*; P=0.000	ρ=0.131; P=0.186	ρ=0.320*; P=0.001
12	ρ=0.374*; P=0.000	ρ=0.402*; P=0.000	ρ=-0.037; P=0.708	ρ=0.215*; P=0.027
13	ρ=0.617*; P=0.000	ρ=0.501*; P=0.000	ρ=0.345*; P=0.000	ρ=0.475*; P=0.000
14	ρ=0.206*; P=0.027	ρ=0.249*; P=0.007	ρ=0.599*; P=0.000	ρ=0.311*; P=0.001
15	ρ=0.534*; P=0.000	ρ=-0.030; P=0.778	ρ=-0.010; P=0.925	ρ=-0.125; P=0.235
16	ρ=0.477*; P=0.000	ρ=0.035; P=0.742	ρ=-0.138; P=0.189	ρ=-0.056; P=0.593
17	ρ=0.844*; P=0.000	ρ=0.638*; P=0.000	ρ=0.042; P=0.680	ρ=0.534*; P=0.000
18	ρ=0.738*; P=0.000	ρ=0.445*; P=0.000	ρ=0.057; P=0.576	ρ=0.374*; P=0.000
19	ρ=0.456*; P=0.000	ρ=0.218*; P=0.024	ρ=0.092; P=0.346	ρ=0.168; P=0.084
20	ρ=0.806*; P=0.000	ρ=0.488*; P=0.000	ρ=0.242; P=0.012	ρ=0.358*; P=0.000

* Statistical significant (P<0.05).