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Case Report

Journal of Medical Practice and Review

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Discrimination of Level Walking, Stairway Ascending and Descending by Length and Direction of the Acceleration Vector

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ARTICLE INFO

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Keywords: Discrimination of Level Walking, Stairway Ascending and Descending by Length and Direction of the Acceleration Vector

ABSTRACT

Angle of inclination of the acceleration vector , an extension of the concept of the azimuth angle to the acceleration due to the resultant force of the gravitational acceleration and the human body in motion . Flat ground walking , the slope of the acceleration vector obtained by measuring the riser and down stairs in a three-axis acceleration sensor , an attempt was made to identify the length of the azimuth angle and vector . Flat ground walking , the down and climbing the stairs , have found the inclination angle of the acceleration vector , a characteristic pattern that can be identification of these walking to the time change of the azimuth angle and length . Compared with the flat land walking , during stair climbing range of changes in tilt angle shifts toward the smaller value , during down stairs increased vector length .

I. Introduction:

By the power shortage caused by the 2011 Tohoku-Pacific Ocean earthquake , climb the long staircase of such high-rise tower apartment came into the daily lives of many of the Japanese [1] . Be the same number of steps as the flat land walking , stair climbing causes a heavy burden , stairs down is likely to damage the foot [1] . Since the nuclear power plant is completely stopped by the political judgment , even in the now , the Japanese are facing a crisis of power shortage . Accordingly , stair climbing is to should be added to the physical activity training program , physical activity evaluation device should be able to identify the level ground walking and stair climbing .Originally, postural information such as tilt angle and azimuth angle of 3 axes acceleration sensor attached portion of body ca be calculated only when any acceleration other than a gravitational acceleration do not exist. In this study, we extend the concept of tilt angle and azimuth angle to the accelerations generated by resultant force of gravity and human movement, and tried to discriminate level walking, stairway ascending and descending by these parameters.

II. Measurement:

A. Measuring device:

The measuring device used for this study was a small (40 x 39 x 8 mm), lightweight (14g) data logger (M-BIT, RIE, Japan). Although, we only use up and down direction acceleration data in this study, M-BIT could measure 3-axes acceleration, ECG and body surface temperature. The M-BIT includes an ECG measuring circuit, an accelerometer, a temperature sensor, 32 M-bytes of memory, a USB connection plug, snap fasteners for electrodes, and a coin battery. The acceleration sampling frequency was 128 Hz. Details of the M-BIT data logger are publicly available [3].

B. Subject:

Subjects were a 54 years-old non athlete and fat male, and under graduate students of the Department of Physical Education of a university (Tokyo, Japan). Students were prime players of their university soccer, rugby football, Basket-ball, volley-ball and boxing teams, and were sport elite.

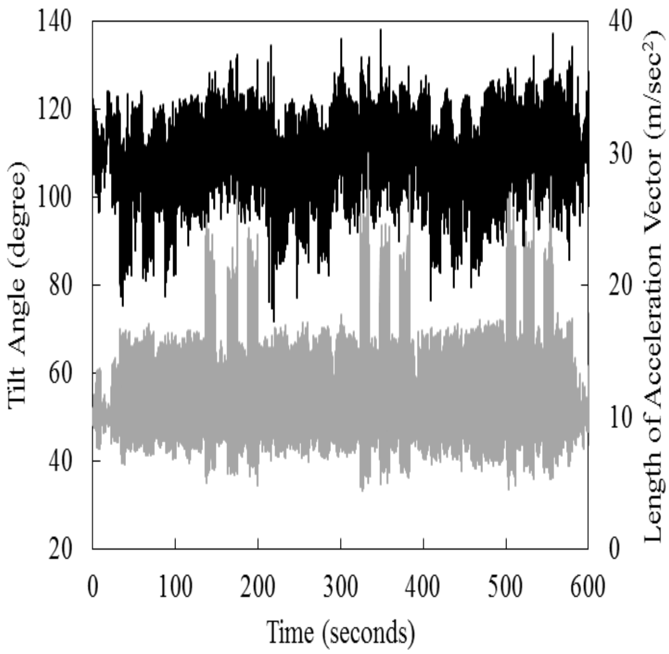
C. Stairway ascending and descending, and level walking:

We used the building of 4 stories of reinforced concrete in which stairways were installed in both ends. The distance between stairways was about 50m. We ascend stairways from the first floor to the fourth floor after equipping M-BIT to the chest with ECG electrodes, walked the passage of concrete, descending stairways to the first floor, and walked the passage of concrete to the start point, 3 round. We walked usually in the relaxed status.

D. The direction and length of the acceleration vector

We defined tilt angle as the angle made by the horizontal pane and the M-BIT plane (=plane of attached body surface) which is consisted by the upright axis and left-right axis of M-BIT, when the upright direction (the direction of upright acceleration detection axis) of M-BIT was in the same plane (vertical plane) with the vertical direction. We defined azimuth angle as the measure of rotation of M-BIT's upright axes in the M-BIT plane.

We extended the method to obtain these tilt and azimuth angle from gravitational acceleration, to accelerations caused by resultant force of gravity and human movement. As the third parameter, we used the length of acceleration vector's length.



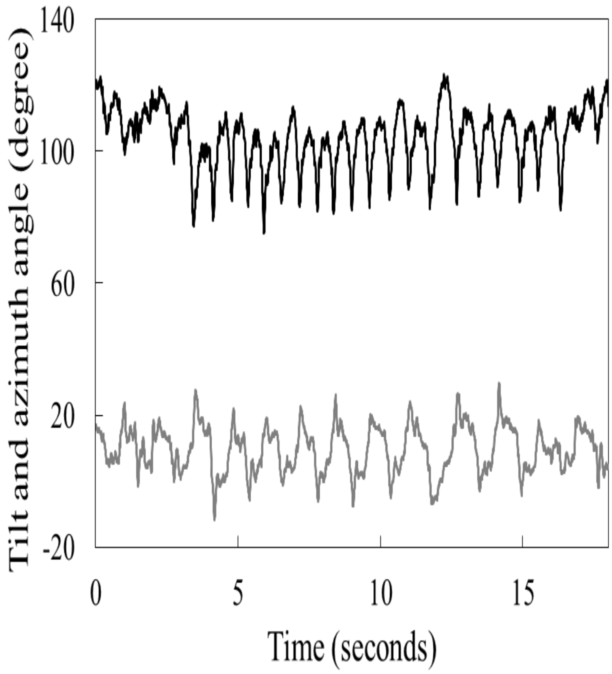


Figure 1. Example of a tilt angle and length of acceleration vector variation during 3 round walking of a 4 stories building. (black line: tilt angle, gray line:length)

III. RESULTS AND DISCUSSION

An example of the time variation of the tilt angle and the length of the acceleration vector during 3 rounds of school buildings is shown in Fig 1. As compared with level walking, the stairway ascending was discriminated by the moving of variation range of a tilt angle to the smaller value side and the spreading of their range, and the stairway descending was discriminated by the increase of the acceleration vectors length. The time variation of the tilt angle and the azimuth angle during level walking was shown in Fig 2. With the period of one step, the tilt angle changed in 100 to 120 degrees. Since the subject of this data is fat and M-BIT was equipped at his rising chest, the value of tilt angle thought to be ranged bigger than 90 degrees. At the time point of downward peak of the tilt angle, the swing leg was thought to be grounded in front of subject's body. The time variation of the tilt angle and azimuth angle during ascending stair way was shown in Fig 3. During ascending stairway, as compared with level walking, the upper boundary of the variation range of the tilt angle was lowered, and the range of changing was increased.

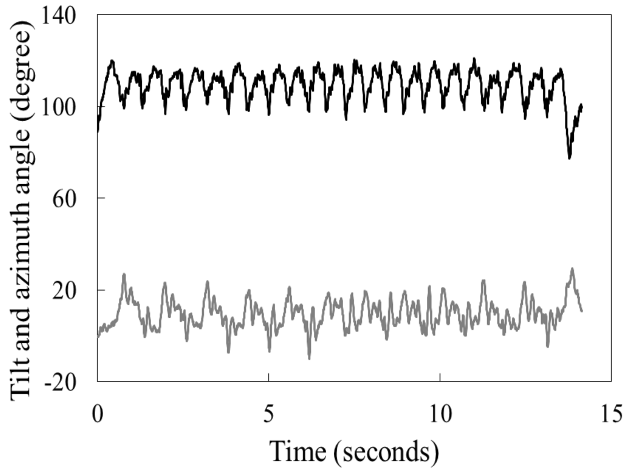


Figure 2. Example of a tilt and azimuth angle variation during level walking. (black line: tilt angle, gray line: azimuth angle)

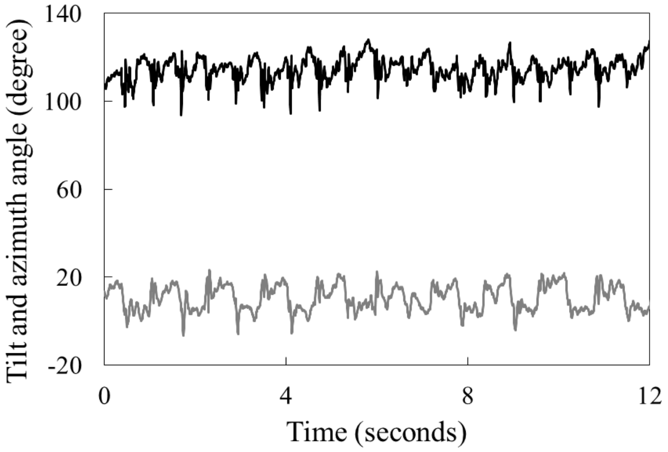


Figure 3. Example of a tilt and azimuth angle variation during stairway ascending. (black line: tilt angle, gray line: azimuth angle)

Since the time fraction of one leg support of weight increased as compared with the case of level walking, the pattern of the azimuth angle variation was thought to be become similar to a step function, and its period corresponded to two steps. Furthermore, in ascending stairways, when brought up a leg during single leg support period or brought up whole body by moving weight support leg to front and upper leg, body may move to right and left with increasing azimuth angle's variation.The time variation of the tilt angle and the azimuth angle during descending stairway was shown in Fig 4. The tilt angle stayed larger value almost all the times in the period and sharp downward peak was observed. On the other hands, azimuth angle showed box-shaped wave form of 2 steps period and stable amplitude. In Fig 5, we compared time variations of length of acceleration vectors of level walking, stairway ascending and descending. In level walking, the amount of length increasing and the time fraction of increased zone during period were rather small. In stairway ascending, both of increase amount and time fraction were increased. Most significant feature of stairway descending was the existence of sharp large

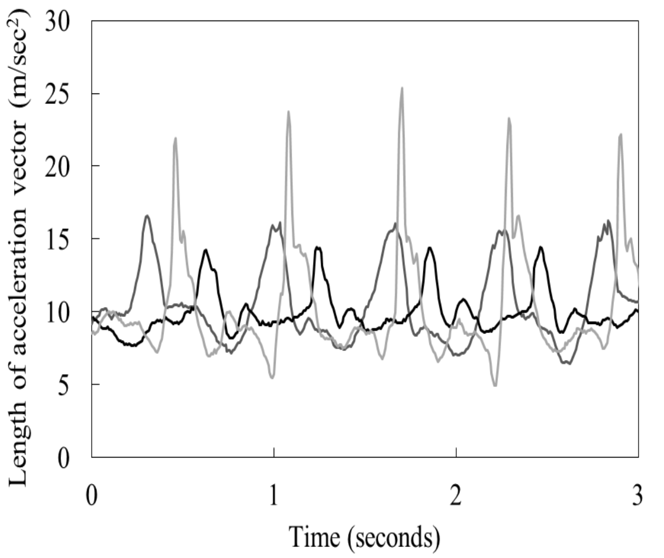


Figure 4. Example of a tilt and azimuth angle variation during stairway descending. (black line: tilt angle, gray line: azimuth angle)

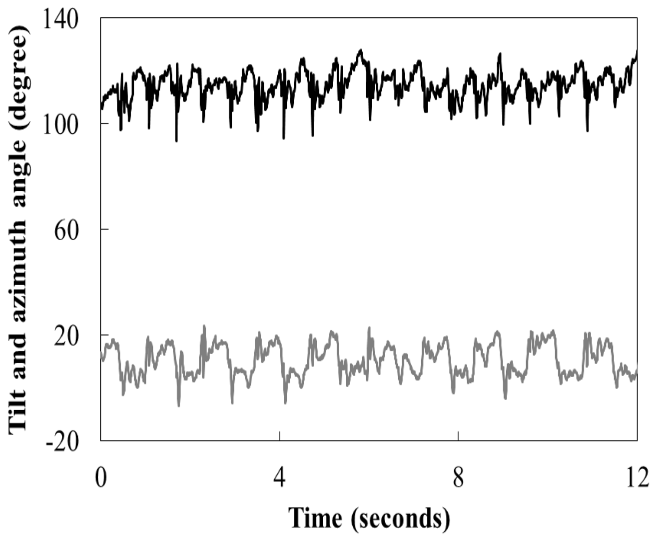


Figure 5. Example of time variations of length of acceleration vector during level walking, stairway

ascending and descending. (black line: level walking, dark gray line: stairway ascending, light gray line: stairway descending)

We investigated the quantifying parameter of these discriminable features. Since we had to consider the periodicity of walking, the length of analysis epoch should correspond to frequency analysis with FFT. The time length which subjects needed to ascend or descend of stairways corresponding 1 story was around fifteen seconds, we set the epoch length as 8 seconds, 1024 points.

We obtained number of data of average period (NDP), and the number of steps (NS)in analysis epoch by the FFT analysis of tilt angle time series data. By averaging NS times a NDP data of tilt and azimuth angle data, we obtained AVERAGE TILT and AVERAGE AZIMUTH for each epoch. On the other hands, we obtained maximum and minimum values of tilt and azimuth angle and length of vector in each period, and as averages of these values within epoch, we obtained TILT MAX, TILT MIN, AZIMUTH MAX, AZIMUTH MIN, LENGTH MAX and LENGTH MIN. Although, with the combination of TILT AVERAGE and LENGTH MAX, we could discriminate the level walking, stairways ascending and descending in a subject as shown in Fig.6, inter subject difference of these values were rather large, and, it was impossible to find discriminating thresholds of these values common for the all subjects.

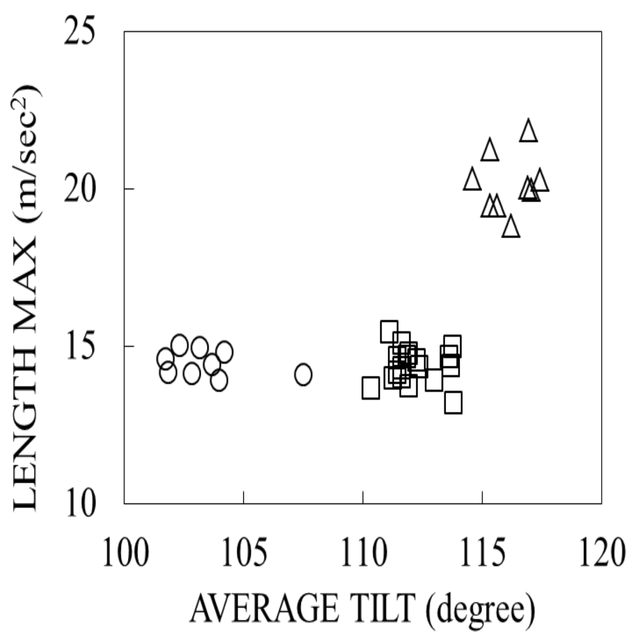
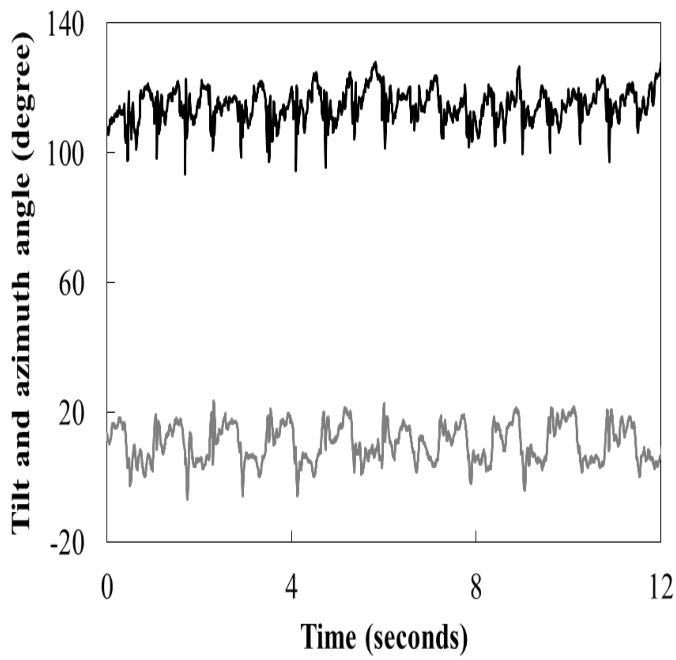


Figure 6. Distributions of AVERAGE TILT and LENGTH MAX of a subject. (square: level walking, circle: ascending stairway, triangle: descending stairway)



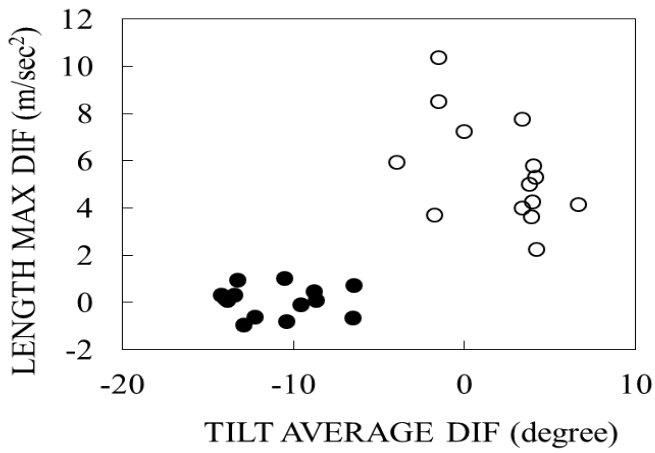


Figure 7. Distributions of TILT AVERAGE DIF and LENGTH MAX DIF of all the subjects. (black circle: ascending stairway, white circle: descending stairway)

To demonstrate the situation shown in Fig.6 were common in all the subjects, old fat non athlete and young sport elites, we focused on the relative difference to level walking. First, we obtained averages of TILT AVERAGE and LENGTH MAX at level walking, stairway ascending and descending, then we calculated their difference with level walking, TILT AVERAGE DIF and LENGTH MAX DIF. In Fig.7, values of these parameters for ascending and descending stairway of all the subjects were shown. Clearly, level walking, ascending and descending stairways were commonly separated.

REFERENCES:

1. H. Sugano, S. Shirouzu and S. Katayama: Example of Mental Stress and Physical Load Due to the 2011 Off the Pacific Coast of Tohoku Earthquake and Accompanying Confusions. Human Development for All **1**: 1-8, 2011

2. S. Shirouzu and A. Shirouzu: Companion for Jogging and Walking, Estimating Walking and Jogging Speed. Human Development for All **1**: 117-124, 2011

3. S. Shirouzu, S. Katayama and T. Masaki: 24 hours Monitoring of Activities of Autonomic Nerves of Four and Five Years Old Children. Human Development for All **1**: 32-41, 2011

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