Evaluation of the balance capabilities of elderly people rising in the longitudinal direction

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Abstract

In this study, balancing capability in the longitudinal direction during rising from seated position was evaluated for the elderly. In particular, influence of rising speed at the moment of leaving the seat, referred to here as the "seat-off," on balancing capability was examined, since it affects the occurrence of falls. Twenty eight elderly individuals were participated in the study, and they were divided into two groups based on their experience of falls in the past: 19 in the stable rising group and 9 in the unstable rising group. Body movement and corresponding ground reaction forces during rising motion at two different speeds were measured for each subject using a motion capture system and a force plate, respectively, from which "seat-off parameters" that could characterize seat-off motion were obtained. Seat-off parameter values for the stable and unstable rising groups were separately distributed in the seat-off parameter space, forming two distinguished clusters. It was shown that the cluster for the unstable rising group was further divided into two sub-clusters. The result implies two types of instability during rising from seated position: an instability in the forward direction group and instability in the backward direction.

Keywords: the balancing capabilities in the longitudinal direction, seat-off parameters, fall.

1. Introduction

According to the 2014 Ministry of Health, Labour and Welfare's comprehensive Survey of living conditions, elderly having come to need assistance or nursing care in life have been reported as making up more than 14 percent of those injured in falling incidents[1]. As the ability to control the body reduces due to aging and degeneration, the risk of falling at the time of rising is higher. In addition, when entering a vicious circle of constantly repetitively falling, the daily-life ability of the elderly is significantly limited [2-7].

Therefore, to support the independent daily life of the elderly by preventing falling in advance, it is important to prevent the vicious cycle of falling regularly and repetitively [8]. In addition, preventing people from requiring care or assistance after falling, not only elderly people, is a major problem that is currently being faced by society, and is a trait characteristic of an ultra-aging society [9-10]. Furthermore, according to a report by the Ministry of Health, Labour and Welfare on falling mechanisms of the elderly, there appears to be a higher frequency of falls while standing or walking [1]. Among these, it is difficult to determine the specific reason because the amount of motion parameters is too large. These parameters include environmental problems and regulations for performing operations to diagnose the falling direction during walking.

However, it is considered to be possible to identify the tipping direction during rising, rather than during walking since the amount of aforementioned parameters is comparitively limited [11]. In other words, there are kinematic and the dynamic analyses for grasping the balance capability during rising of the elderly, and it is possible that aid for preventing falling can be offered by predicting the direction which people tend to fall.

Conducting studies on rising behaviors in the past, including seat angles, changes in sitting posture, etc. have been pursued to explore the reactivity of a subject to changes in external environmental factors [12-15]. Actual causes of falls of elderly people, rather than simply looking at the external environment, have been performed in smaller numbers, due to the difficulty of the elder's unconscious environment being different from normal.

For example, in the case of the elder being in an excited state or in the case that the elder possesses a strong desire to void, by hurrying to get up faster than usual, or oppositely in a situation of decreased arousal, rising is slower than usual. Thus emotional and physiological concerns might have a significant effect on the stability of rising. If this rising speed exceeds the allowable capacity of the elder's own rising speed, and there is a change in the person's attitude control ability in response to rising up speed, the rising action is thought to become unstable.

In this study, the internal environment as well as the external environment was examined in order to evaluate how the longitudinal balancing capability at varying rising speeds greatly affect the fall in rising [16]. In particular, longitudinal balancing capability at seat-off, which was associated with falls, was examined closely [17-18]. As a measure of the longitudinal balancing capacity at the time of seat-off, seat-off parameters consisting of Center Of Gravity (COG)-heel horizontal distance and COG horizontal velocity at the time of seat-off, and at the same time measure the floor reaction force were created and examined.

2. Method

Subjects were 28 healthy elderly people of ages 74-92 that are residents in an elderly care house (13 males, 15 females). ADL of all subjects was self-level, including the outing. Of the elderly 28 people, 9 people had a history of falling more than 2 times (4 male, 5 female). These people were grouped into the unstable rising group. The other 19 people were grouped into a stable rising group, and the following experiments were performed. In addition, this study was approved by the Okayama University Ethics Committee (approval No. 1824), all subjects received an adequate description of the experiment, and only participated in the experiment after formally agreeing to.

For the experiment, an armrest free chair, with a seat height equivalent to the lower leg length of the subject was used. The starting limb position was a static sitting posture defined as having a hip-knee-ankle joint angle of 90 °, and allowed the subjects trunk to remain in the vertical position as best as possible. The end limb position was the still standing posture in which the head and trunk are held in a vertical position. In addition, both hands were placed in front of the chest, a legs apart movement was not allowed. Just before the start of the rising motion, one of the challenges, of being either "fastest" or "slowest" was taught randomly and the rising operation was performed five times, respectively.

Image data of the subject at two speeds of rising movement were acquired and analyzed by a motion capture system (Move-tr./3D, library). The sampling rate of the images was captured using image analysis software at 50fps, the created seat-off parameters consisting of COG-heel horizontal distance and COG horizontal velocity at the time of seat-off were analyzed, and the width of seat-off parameters between 2 task were calculated, in order to examine their association.

Markers at, parietal, both ear holes, both acromions , both humerus lateral epicondyles, both radial styloids, both third finger apexes, both greater trochanters, both knees cleft center, both malleolus lateralis, and both head of fifth metatarsals, were affixed to a total of 18 locations. To calculate the synthesized body's center of gravity, in addition to these marker points, the head point, breast point and waist point were defined as follows: The head point: the midpoint of the left and right ear hole markers. The chest point: the midpoint between the left and right acromion markers. The waist point: the midpoint of the left and right of the greater trochanter markers. The timing of seat-off was determined by moving image data captured in the analysis software by frame advance reproduction.

The COG-heel horizontal distance at the moment of seat-off was defined as the horizontal distance between a part of the supporting basal plane malleolus lateralis and the body's center of gravity. The COG horizontal velocity at seat-off was defined as the average velocity of the preceding frame and one following frame, which were calculated (Fig. 1). The horizontal and vertical component forces at the time of seat-off by force plate (CFP03000A, Leptrino) were measured simultaneously, and the association between them and the seat-off parameter's width were examined (Fig. 2).

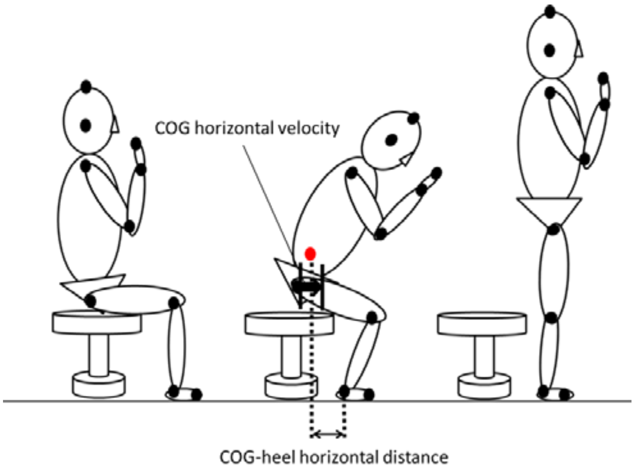


Figure 1 Definition of COG-heel horizontal distance and COG horizontal velocity

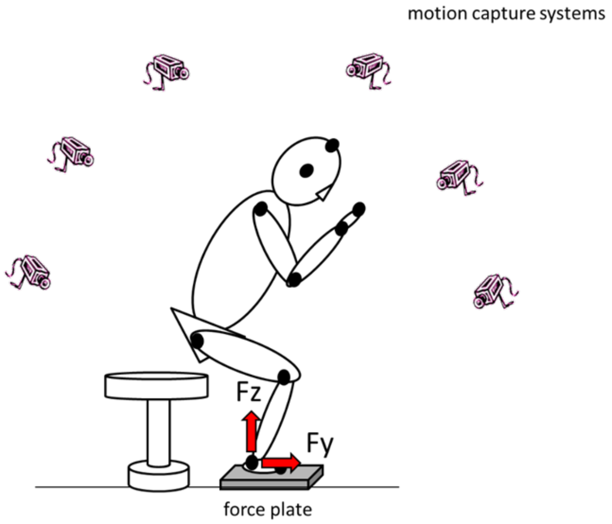


Figure 2 Motion capture systems and Floor reaction force plate

Seat-off parameters were created by COG-heel horizontal distance and the COG horizontal velocity of the mean value of the fastest and slowest rising speed over the five attempts. Fig. 3 shows the definition of seat-off parameters and the distribution of seat-off parameters. The horizontal axis was the width of COG-heel horizontal distance of the width, and the vertical axis was the width of the COG horizontal velocity. The visual distribution of the visual seat-off parameters were attempted to grasp the longitudinal balancing capability at the seat-off. For the floor reaction force at seat-off, the average value of the floor reaction force horizontal and vertical components of the fastest and the slowest of the five attempts were calculated for each subject.

In addition, these average values were plotted on a graph where the horizontal axis was the width of the floor reaction force horizontal component(Fy－F’y), and the vertical axis was the width of the floor reaction force vertical component(Fz－F’z) during the slowest and fastest attempts. The relation between seat-off parameters was analyzed, and the longitudinal balancing ability at seat-off was verified mechanically(Fig. 4).

3. Results

The seat-off parameters of all subjects are shown in Fig. 5. The distribution of seat-off parameters are shown in Fig. 6. The results of examining the distribution of the seat-off parameters, showed that the unstable rising group went through the stable rising group, and was symmetrically distributed into a 5 person group and a 4 person group. This result was reflected in the distribution into a form which is supported by the experimental results from the floor reaction force distribution by motion analysis (Fig. 7).

The 5 person group in the upper left hand corner were defined as unstable rising group A, and the 4 person group distributed to the right bottom were defined unstable rising group B. Including the stable rising group, the three groups in the task were compared and a comparison of the floor reaction force measurement value of the width of the seat-off parameters was carried out (Table 1, Table 2). For the width of the seat-off parameters in the three groups, the width of the COG-heel horizontal distance at seat-off was compared using an analysis of variance among the three groups, and no significant difference among the three groups was found.

Since the COG horizontal velocity width was significantly different among the three groups, the results were compared using the Ryan method and the unstable rising group was found to have a significantly smaller velocity than the other two groups. The results of the comparison of the floor reaction forces among 3 groups was performed and shown below:

Since the Fy component force for the fastest task varied significantly between the three groups, the results were compared using the Ryan method. It was found that the force was significantly greater for unstable standing group A than for the other two groups. Since the Fz component force for the fastest task was significantly different between the three groups, the results were also compared using the Ryan method The component force was found to be significantly greater in unstable standing group B than in the other two groups. Since the Fy component force for the slowest task was significantly different among the three groups. The force was significantly greater for unstable standing group B than for the other two groups. As for the Fz component force for the slowest task, it was not found to be significantly different among the three groups (Table 1, 2).

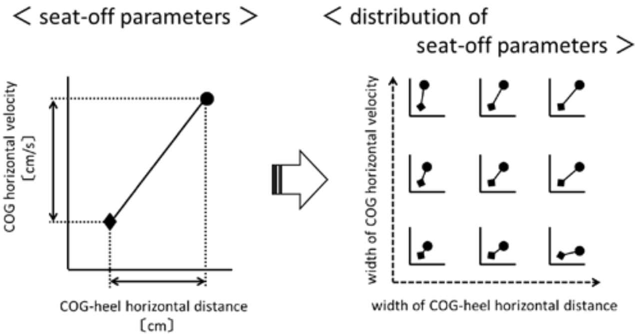


Figure 3 Schematic diagram of seat-off parameters and the distribution at the seat-off

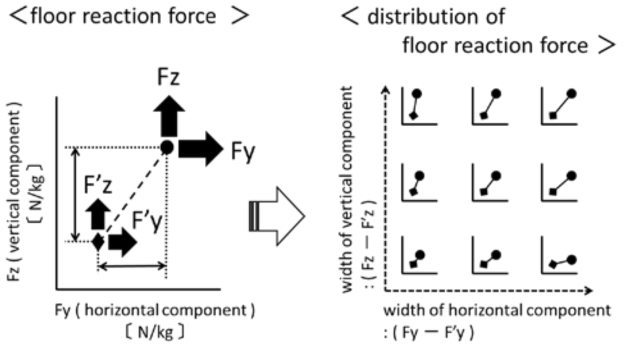


Figure 4 Schematic diagram of floor reaction force and the distribution at the seat-off

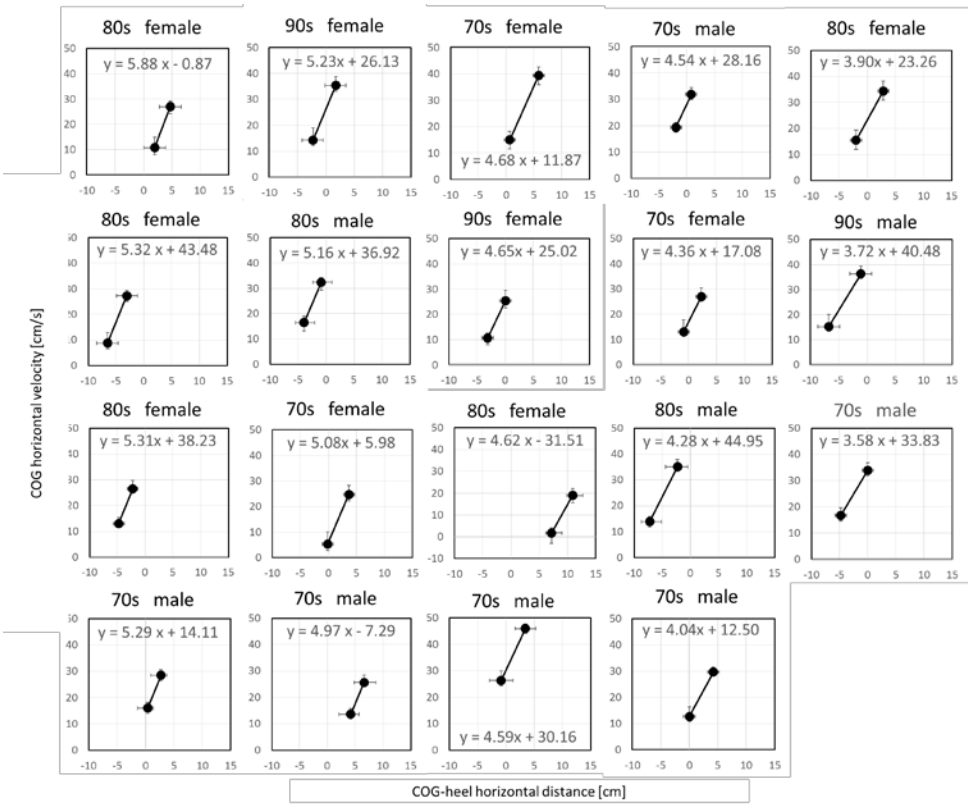
Table 1 Width of seat-off parameters at the seat-off

	width of COG-heel horizontal distance	width of COG horizontal velocity
unstable rising group A	2.29 ± 0.16	18.54 ± 1.03
unstable rising group B	4.47 ± 0.33	13.03 ± 1.04*
stable rising group	3.78 ± 0.97	17.21 ± 3.38

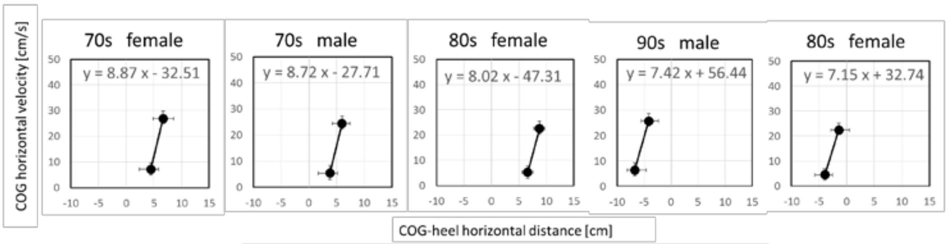
width of COG-heel horizontal distance : average[cm]±SD,
width of COG horizontal velocity : average[cm/s]±SD $p<0.01$

Table 2 Floor reaction force at the seat-off

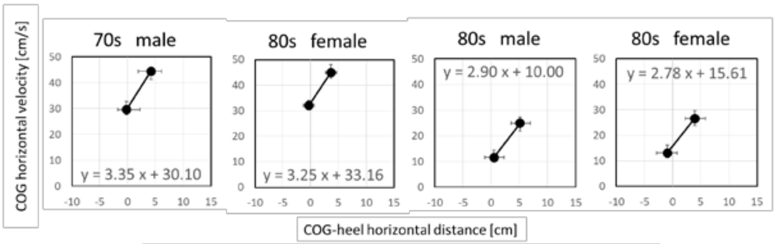
	at fastest		at slowest	
	Fy	Fz	Fy	Fz
unstable rising group A	0.29 ± 0.02*	1.18 ± 0.02	0.12 ± 0.04	1.07 ± 0.01
unstable rising group B	0.22 ± 0.08	1.28 ± 0.04*	0.19 ± 0.01*	1.05 ± 0.03
stable rising group	0.19 ± 0.02	1.23 ± 0.02	0.14 ± 0.03	1.07 ± 0.02



(a) stable rising group



(b) unstable rising group A



(c) unstable rising group B

Figure 5 Seat-off parameters of all subjects

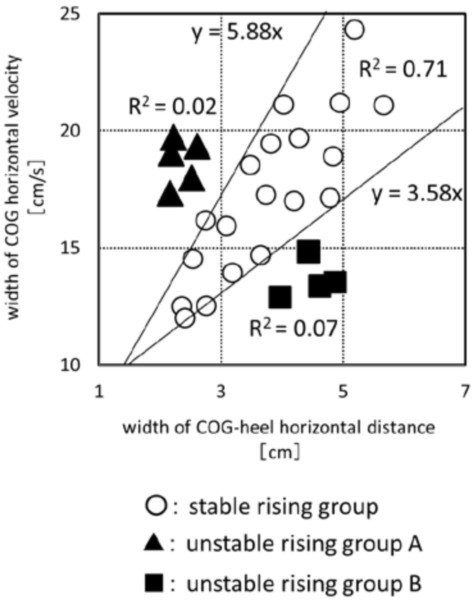


Figure 6 Distribution of seat-off parameters of all sub jects

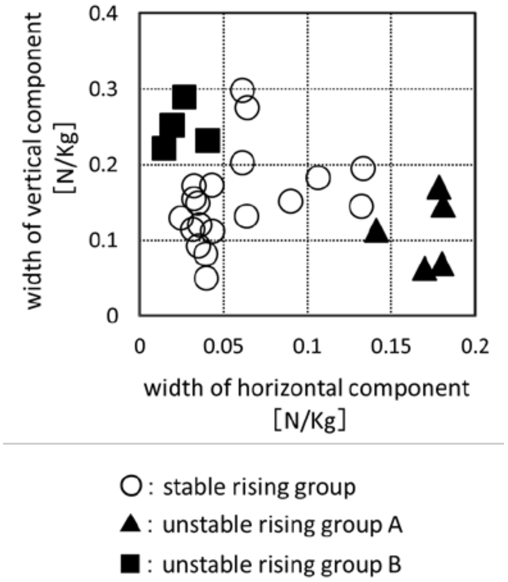


Figure 7 Distribution of floor reaction forces of all sub jects

4. Discussion

The inclination of the distribution of the seat-off parameters for the stable rising group (9 males, 10 females) converged within a certain range. The inclination of the distribution of the seat-off parameters for the remaining two groups (4 males, 5 females) deviated from this range, especially in those who had more than two fall experiences in the survey taken during the past year. In the stable rising group, while a strong positive correlation was observed between the COG-heel horizontal distance width and the COG horizontal velocity width, a correlation was not observed in the unstable rising group. In this experiment, when analyzing the results of the distribution of seat-off parameters of the three groups, including the corresponding property was found to be necessary for changes in rising speed.

In the stable rising group, it was presumed that at seat-off, in order to obtain stability corresponding to the rising speed, the COG horizontal velocity must be controlled by adjusting the COG-heel horizontal distance and stabilizing the body by governing the COG position within the supporting basal plane. Additionally, as the seat-off parameters are distributed in the lower left region, if the distance between the slowest and fastest is short, it means that the possible range of rising actions is very limited. Conversely, the greater the seat-off parameters are distributed in the upper right, and if the slowest to fastest distance is long, it means that the possible range of rising actions is very broad.

On the other hand, the disturbed balance of COG-heel horizontal distance and COG horizontal velocity during seat-off in the unstable rising may not act reciprocally, and it is inferred that this is the cause of the instability. In other words, when the COG-heel horizontal distance and the COG horizontal velocity vary while maintaining a proportional relationship within a fixed range, this mechanism leads to stability in rising. However, when deviated from, rising becomes unstable. From the fact that the distribution of seat-off parameters for the unstable rising group A had been displaced into the upper left side of the stable rising group, it was inferred to have a tendency of being excessively dependent on the COG horizontal velocity in order to respond to changes in rising speed.

Similarly, the distribution of seat-off parameters for unstable rising group B had been displaced into the lower right side of the stable rising group, and it was inferred to have a tendency of being excessively dependent on the COG-heel horizontal distance in order to respond to changes in standing speed. The distribution of the experimental seat-off parameters of the stable rising group, was within the range of y = 5.88x and y = 3.58x, the seat-off parameters of unstable rising group A and unstable rising group B deviated from this range.

In addition, the potential characteristics at the time of rising for the unstable rising group were analyzed from the width of the seat-off parameters and the floor reaction force values. The seat-off parameters of unstable rising group A (2 males, 3 females) had the minimum COG-heel horizontal distance width among the three groups, and the largest COG horizontal velocity width among the three groups. For the floor reaction force, the Fy component force at the time of fastest task was significantly larger than that of the other two groups.

Therefore, it was inferred that unstable rising group A has a tendency for its balance to collapse in a forward direction, especially when attempting to rise quickly. Among the three groups, the seat-off parameters of unstable rising group B (2 males and 2 females) exhibited the maximum COG-heel horizontal distance width and the minimum COG horizontal velocity width. In addition, the Fz component force when performing the fastest task and the Fy component force when performing the slowest task were significantly greater than the other two groups. From these results, it was presumed there is a tendency such as the following:

In unstable rising group B, when rising particularly quickly, balance in the rear direction is likely to collapse, and forward balance is likely to collapse when attempting to rise slowly(Fig. 8).

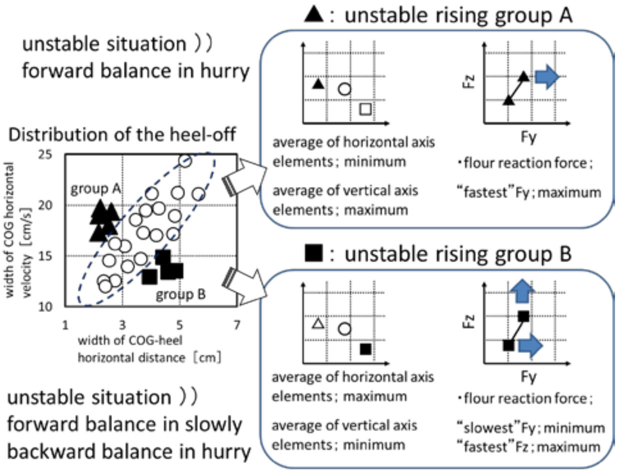


Figure 8 Features of instability at the time of standing of the 2 unstable rising groups

5. Conclusion

An evaluation of longitudinal balancing capacity during rising in the elderly was attempted as follows:

(1)Seat-off parameters consisting of the COG-heel horizontal distance and COG horizontal velocity at seat-off were created.

(2)By analyzing the distribution of seat-off parameters, longitudinal balancing ability was able to be grasped.

(3)Floor reaction forces at the time of seat-off were verified.

As a result, elderly subjects exhibiting instability during rising were divided into two groups, and the following characteristics were revealed at the time of each rising behavior.

(1)Unstable balance in the forward direction-types: there was instability in forward balance, especially when attempting to rise in a hurry.

(2)Unstable balance in the rear direction-type: instability exists in backward balance when attempting to rise up in a hurry, and instability in forward balance when trying to rise slowly.

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