Original Article

Preliminary study of effect of readiness on circulatory regulation when standing up from low chair

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Abstract

Falling accidents can occur when individuals suddenly stand up from a sitting position. Rapid orthostatic hypotension can occur and impair the blood supply to the brain. We tried to verify whether prior notice affect the change in blood pressure. This study investigated the effects of anticipatory control on changes in the circulatory system. Eight healthy adults (mean age, 21.5 years; range, 19-23 years, 163 ± 2 cm, 58 ± 4 kg) were asked to stand up with or without prior notification from chairs of two different heights (20 or 40 cm). Electroencephalography and cerebral circulation were monitored continuously, and blood pressure was compared before and after standing. Though no statistically significant differences were observed for individual indices of heart rate, blood pressure, and cerebral blood flow between the presence and absence of prior notice, a significant difference was found for sympathetic nerve activity which can be expected to buffer any rapid changes in hemodynamics. In addition, the effects of chair height had a remarkable impact in this study. The 20-cm chair height significantly caused a larger load on hemodynamics than the 40-cm height. In conclusion, sitting-standing position in daily living space is thought to be important for any people, and anticipatory control may be help for avoiding orthostatic hypotension in clinical settings.

Key words: orthostatic hypotension, circulatory regulation, heart rate, prior notification, anticipatory control

Introduction

Some falling accidents occur when people suddenly stand up from a sitting position while in the bathroom or living room. These types of falls can occur during activities of daily living. The cause of such falls appears to be orthostatic hypotension (cerebral anaemia)\(^1\). Blood pressure (BP) regulation after standing up requires an increase in heart rate (HR) and the maintenance of venous flow via the contraction of skeletal muscle.

In terms of circulatory regulation during head-up tilt, various autonomic nervous system function tests for orthostatic hypotension have been conducted to ascertain changes in BP and HR\(^5\). The head-up tilt test is a common test used in medical diagnosis and can be performed either passively or actively. With the passive head-up tilt test, the subject is placed in a supine position on a table and then BP and HR are continuously measured while the patient lies down for 10 min and tilts his/her head up at 60–80° for 10 min. In healthy individuals, both systolic blood pressure (SBP) and diastolic blood pressure (DBP) increase by approximately 10 mmHg and HR increases from 5 to 25 beats/min during this test. However, in patients with orthostatic hypotension, SBP decreases by ≥21 mmHg and HR increases by ≥26 beats/min during head-up tilt. Changes in BP and HR are used for diagnostic purposes.

Because of recent advances in analytical methods, studies have been actively conducted to ascertain changes in HR during head-up tilt, and many studies have discussed this issue. Among the elderly and invalids with insufficient regulatory function, rapid decreases in BP can block the supply of blood to the brain, resulting in orthostatic hypotension\(^6\). Some
studies have documented differences between healthy adults and the elderly with reduced autonomic movements. When assisting such elderly individuals and invalids in changing body position in clinical settings, talking to the individual first and assisting them with moving are important. However, we think the young or healthy adults have a similar risk of alteration of autonomic movements and BP.

The present study investigated the effects of anticipatory control (the body getting ready in anticipation of postural changes in the immediate future) on the basis of changes in the circulatory system.

**Methods**

1. **Participants**

   The study subjects comprised 8 healthy adults (163±2 cm, 58±4 kg, 4 men, 4 women) with a mean age of 21.5 years (range, 19 – 23 years) of Japanese.

2. **Instrumentation**

   In the study, chairs with two different heights (seat height, 20 or 40 cm) were used. The subjects were asked to stand up from a 20- or 40-cm chair with or without prior notification (PN) in a random sequence. The height of 40 cm is of usual chair and that of 20 cm is of comfortable low chair for Japanese room.

   The test was conducted as follows. First, each subject was instructed to sit in a chair in a comfortable position, and once biological reactions stabilized, the subject was asked to rest in the sitting position for 5 min and then to stand up and remain standing for 3 min. With PN, the subject was notified every minute and 30 and 10s before standing up, after which a countdown was started 5s before the subject was asked to stand up. All subjects took approximately 1s to stand up. During the test, electroencephalogram was continuously monitored via lead II, and cerebral circulation was continuously measured using near-infrared brain oxygen monitor (OM–200 near-infrared cerebral oxygen monitor; Shimadzu, Kyoto, Japan). BP waveforms per heartbeat by tonometry before and after standing up was recorded using an automatic continuous non-invasive sphygmomanometer (JENTOW–7700; Colin Japan, Tokyo, Japan). BP changes were recorded using a data recorder (RD–135T; TEAC, Tokyo, Japan). Recorded data were subjected to automatic haemodynamic and autonomic nervous system activity analysis (Fraclet™, Dainippon Sumitomo Pharma, Tokyo, Japan) with sampling rate of 1kHz–16 bit in analog–to–digital conversion to determine HR, SBP, mean BP, DBP and ECG RR (R–R interval; ms). According to frequency analysis based on wavelet transformation, fluctuations in HR and BP were analyzed by Fraclet™. On the basis of the time (t), scale (a), time shift (b), input time series (f), the wavelet transform is Gabor transform (Gw) and defined as follows:

\[
Gw(b,a) = \int_{-\infty}^{\infty} \frac{1}{\sqrt{a}} \psi \left( \frac{t-b}{a} \right) f(t) dt
\]

Regarding the spectrum of HR fluctuations, the spectral power of low–frequency (LF; 0.04–0.15 Hz) and high–frequency (HF) components (0.15–0.4 Hz) for 30s before and 30s after standing up was calculated, and changes in HF components were used to assess parasympathetic nervous activities. Regarding the spectrum of BP changes, the spectral power of LF components for 30s before and 30s after standing up was assessed on the basis of fluctuations in SBP (SBP–LF, 0.04–0.15 Hz) to evaluate sympathetic nerve activities.

3. **Measurement of cerebral circulation**

   To monitor cerebral circulation, cerebral blood flow (CBF) was measured with OM–200 by placing a sensor on the right forehead above the eyebrow. This device uses near–infrared light and measures changes in haemoglobin levels in the body by spatial analysis based on light diffusion theory.

   The light source for the device is a diode laser with three wavelengths (\( \lambda \): 780, 805 and 830 nm), with light irradiated in that order. On the basis of the degree of change in optical density (OD) at each wavelength (\( \Delta OD\lambda \)), changes in oxyhaemoglobin (\( \Delta HbO_2 \)), deoxyhaemoglobin (\( \Delta HbD \)) and total haemoglobin (\( \Delta HbT \)) were calculated using the formula based on Lambert–Beer’s law.

   Furthermore, using this device, the error between actual biological and theoretical values is corrected by a diffusion equation. Changes captured by the device are relative changes in concentration in individual subjects. In the present study, concentration was
expressed in arbitrary units. Changes in CBF were observed as relative changes in \( \Delta \text{HbO}_2 \) as reported previously 17).

5. Procedure

All procedures were approved by the Research Ethics Committee of Faculty of Medicine, University of Tsukuba. After providing written informed consent, a health survey was conducted prior to the study, and informed consent was obtained from all subjects.

6. Statistical Analysis

The indices of increase in heart rate, decrease of mean BP, oxyhemoglobin changes and the spectral power of low-frequency components of fluctuations in SBP were assessed by Wilcoxon signed-rank test. Data are presented as mean ± SD and levels of \( P < .05 \) are considered statistically significant.

Results

Figure 1 shows typical data obtained from time series of 60s before and 60s after standing up by the present study. This subject was asked to stand up from the 20-cm chair, and changes in HR, BP and cerebral circulation were then compared between standing up with and without PN. In this case, mean BP decreased to 43 mmHg just after standing up (Fig. 1A). Among the group, HR after standing up increased immediately, and decreased within about 30s. The degree of decrease in BP was greater without PN (Fig. 1B). The degrees of decrease in HbO and HbT appeared greater without PN (Fig. 1C), but were not significant differences in group. For
HF component power as assessed by HR fluctuation analysis (Fig. 1D), there was a tendency of power decrease after standing up with PN among the group but was not significant difference. For LF component power as assessed by SBP fluctuation analysis (Fig. 1E), power without PN was low before standing up, but it rapidly increased after standing up. However, with PN, a slight increase was observed before standing up, but the degree of increase was lesser after standing up than after standing up without PN.

Figure 2 compares the rate of maximum increase in HR immediately after standing up in relation to chair height and PN for the 8 subjects. With PN, the mean HR was 72 ± 2 before standing up and 92 ± 3 just after standing up from 20-cm chair. The mean HR was 71 ± 2 before standing up and 84 ± 3 just after standing up from 40-cm chair. Without PN, the mean HR was 72 ± 2 before standing up and 95 ± 3 just after standing up from 20-cm chair. The mean HR was 71 ± 2 before standing up and 85 ± 3 just after standing up from 40-cm chair. The rate of increase in HR without PN tended to be slightly higher, but no significant difference was observed. The degree of increase was significantly greater when standing up from the 20-cm chair than when standing up from the 40-cm chair (P<.05).

Figure 3 compares the rate of maximum decrease in average BP immediately after standing up. With PN, the mean BP was 82 ± 4 before standing up and 62 ± 4 just after standing up from 20-cm chair. The mean BP was 82 ± 4 before standing up and 60 ± 3 just after standing up from 40-cm chair. Without PN, the mean BP was 81 ± 5 before standing up and 47 ± 5 just after standing up from 20-cm chair. The mean BP was 81 ± 5 before standing up and 63 ± 5 just after standing up from 40-cm chair. Although no significant difference existed with respect to PN, when standing up from the 20-cm chair, the degree of decrease without PN was greater than with PN. When standing up with PN, no marked differences existed between standing up from the 20- and 40-cm chairs, but without PN, a significant decrease (P<.05) was observed when standing up from the 20-cm chair.

Figure 4 compares the degree of maximum change in HbO2 immediately after standing up. Although no significant differences existed between standing up with or without PN, HbO2 tended to be lower without PN. A significant difference existed with PN between the 20- and 40-cm chairs (P<.01).

Figures 5 and 6 compare SBP-LF as assessed by SBP fluctuation analysis for 30s before and after standing up. When comparing changes before and after standing up with respect to PN, significant increases were observed after standing up from the 20- and 40-cm chairs without PN. In particular, when standing up from the 20-cm chair, rapid increases
from $1.86 \pm 1.10$ to $6.84 \pm 2.75$ mmHg/Hz were detected. With PN, no significant differences were present at either height (20 and 40 cm), but SBP tended to increase slightly after standing up.

**Discussion**

The present study clarified that when standing up suddenly from a low chair, instantaneous hypotension was observed 10−15s after standing up. As subjects in the present study were healthy adults, no marked hypotension leading to orthostatic hypotension was observed. However, as observed in the representative case, mean BP can decrease to $<60$ mmHg even in healthy adults.

A mean BP of $60$ mmHg has been reported as the limit of automatic regulation of BP in normotensive people.$^{18}$ The present results suggest that this is closely related to low CBF. That is, HbO$_2$ was measured to assess CBF, and markedly low HbO$_2$ was observed in subjects in whom BP decreased markedly.

A limitation of the study was the small sample size. For this reason, these findings cannot be generalized to the broader young people based on this study alone. However, mean BP can drop below $60$ mmHg even in healthy adults, those with reduced autonomic movements like elderly person could be more. Techniques to get ready to stand is extremely important as nursing care technique in order to prevent orthostatic hypotension.

Concerning the extent of the increase of heart rate (HR) directly after standing up, as shown in Figure 2, although the extent of increase was larger when there was no PN than when there was PN, the difference was not significant both at a chair height of 20 cm and at 40 cm. However, there was a large difference in the extent of HR increase between when the height of the chair was 20 cm and when it was 40 cm, and the difference was significant both in the presence and
Concerning the decline in BP directly after standing up, as shown in Figure 3, in the presence of PN, almost no statistical differences were seen between when the chair was 20 cm and when it was 40 cm. Conversely, in the absence of PN, a significant difference was observed between the chair heights. Considering that in Figure 2, HR increased regardless of the height of the chair, it is thought that the necessary reactions needed to compensate for BP decline are engendered by the PN.

Concerning the changes in CBF directly after standing up, as shown in Figure 4, in the absence of PN, there was no significant difference between when the chair was 20 cm and when it was 40 cm. Also, there were no significant differences at the same chair height in the presence or absence of PN. Conversely, in the presence of PN, the CBF decline rate was larger when the chair height was 20 cm than when it was 40 cm. This is the result of the trend toward the cancellation of the effects of PN, as surmised in Figure 3. Combining this with the results for Figure 2, we can conclude that the influence of the difference in chair heights is extremely large.

Concerning the changes in the index of sympathetic nerve activity (SNA) before and after standing up from a 20-cm chair, as shown in Figure 5, although there was an increase in the absence of PN, the difference was not significant. However, in the presence of PN, SNA increased significantly. This shows that when the subject stood up without mental preparation, the sympathetic nerves were excited. Similarly, the SNA index increased after standing up from a 40-cm chair both in the presence and absence of PN, as shown in Figure 6; however, the changes were larger for the 20-cm chair (Figure 5). This suggests that the sympathetic nerves were rapidly excited to compensate for the effects (the rapid decline in BP and CBF, and the increase in HR) of standing up from the lower chair. Furthermore, we surmise that PN serves to quicken the triggering of this excitement beforehand.

In the overall assessment of the results, no statistically significant differences were observed for individual indices of HR, BP, and CBF between the presence and absence of PN. However, as a significant difference was found for SNA, we expect that if sample numbers were to be increased, then results suggesting that PN buffers the load on hemodynamics might be obtained. The presence of PN causes tension not limited to the self-awareness evoked through the sympathetic nervous system; PN also activates regulatory reactions such as vasoconstriction, which would function to buffer any rapid changes in hemodynamics.

In the present study, in which the test subjects were healthy adults, although such responses due to rapid SNA are possible even without PN, autonomic nervous disorders in elderly or ill persons would become a major factor associated with BP declines after standing up. Considering this, we believe that PN of posture changes that will occur when standing up have extreme importance.

While our original research design had no main objective, the effects of chair height had a remarkable impact in this study. In all indices, the difference in chair heights showed some type of significant difference regardless of the presence or absence of PN. We observed that the 20-cm chair height clearly caused a larger load on hemodynamics than the 40-cm height. Our results suggest that the traditional Japanese lifestyle has an inherent risk of major height-induced differences caused by standing up after lying or sitting on tatami mat floors, and that the use of taller chairs may be a way of reducing the risks resulting from hemodynamic regulation effects either to an equivalent extent or beyond the risk reductions caused by the PN.

The Japanese Orthopaedic Association announced in 2013 a “Locomotive Syndrome Risk Test” to predict the risk of locomotive syndrome development. One evaluation scale used in this test is the “Stand-up Test,” which measures lower-limb muscular strength. This tests whether one can raise her/his own body weight on one leg or two legs from a platform height of 10, 20, 30, or 40 cm. Certainly, persons with sufficient muscular strength should be able to raise themselves from any of these heights on just one leg. Yet, from our study results, we hypothesize the following: in the Locomotive Syndrome Risk Test, compared with raising oneself from a 40-cm platform, raising oneself from a 20-cm platform will cause a load on cerebral circulation separate from muscular strength. We also hypothesize that persons in their 70s or approaching that age group who are included in Locomotive Syndrome Risk
Test potentially have a higher risk in addition to those risks related to autonomic regulation functional declines, as discussed in the Introduction section.

**Conclusion**

1. No statistically significant differences were observed for indices of HR, BP, and CBF between the presence and absence of PN.
2. In the presence of PN, SNA increased significantly. It was suggested that the reactions compensate for BP decline when the subject stood up without mental preparation.
3. In indices of HR, BP, and CBF, the difference in chair heights of 20 cm and 40 cm showed some type of significant difference regardless of the presence or absence of PN.

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**Conflict of interest statement**

None of the authors have any conflicts of interest associated with this study.

**References**

椅子からの起立時の循環動体の変化と「事前構え」の\n効果の基礎的検証

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要 旨

日常生活において座った姿勢から急な姿勢変化を行ったときに起きる転倒事故の理由の一部には，起立性低血圧が含まれていると考えられる。事故予防策として，人が立ち上がるときに「声掛け」をすることが予期調節として循環動体に効果を及ぼすかどうかを調べた。8人の健康な成人（19〜23歳の男女各4名，平均身長163±2cm，体重58±4kg）を対象に，異なる高さの椅子（20cmと40cm）で立ち上がってもらい，持続的に循環動体と脳血流量を計測して，事前の声掛けの有無による指標の差異を調べた。その結果，心拍数と血圧，脳血流量には，椅子の高さにかかわらず声掛けの有無による有意差はみられなかったが，交感神経の活動には有意差がみられた。これは，循環動態の急激な変化を補償する反応であることを示唆している。一方，予告の有無にかかわらず，椅子の高さが20cmのときは40cmのときより有意に起立直後の心拍数が上がり，血圧が低下し，脳血流量が低下しており，低い位置からの立ち上がりが循環動態に対してより強い負荷をかけたことを示した。

キーワード：血圧，心拍数，起立性低血圧，事前構え，予期調節