The effect of perception of seat width on back-to-sit task

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Abstract. [Purpose] The movement trajectory in daily motion is strongly associated with information regarding the properties of the environment. In the case of the back-to-sit task, it may vary according to chair property. The purpose of this study was to investigate whether trajectory formation in back-to-sit tasks by healthy adults depends on seat width information. [Participants and Methods] Ten healthy young males performed a back-to-sit task in 5 seat width conditions (80%, 90%, 100%, 110%, and 120% of each participant’s buttock breadth). The motion analysis system and force plates were set at a sampling frequency of 250 Hz. The spatial and temporal variables were calculated to examine the effect of seat width. A questionnaire was also administered to examine whether the participants were aware of each seat width in comparison with their own buttock breadth as narrow or large. [Results] The questionnaire results showed that many participants were aware but some were unaware of the relative comparison of their size to the seat width. Nevertheless, the spatial and temporal variables were invariant under the different seat width conditions. [Conclusion] In healthy adults, the trajectory formation in back-to-sit tasks is not dependent on the perception of seat width information under their variability as per daily situations.

Key words: Back-to-sit, Seat width, Perception

INTRODUCTION

In order to adapt to the requirements of various environment and motor tasks, we must accurately perceive intrinsic (body property) and extrinsic (environment property) constraints. The misjudgment of them, either overestimating or underestimating, may lead to trouble in daily living. A previous study showed older adults had a tendency to overestimate their own reaching ability compared to healthy adults, and the stronger this tendency, the lower their physical ability¹. Furthermore, these errors in physical strength awareness can possibly raise the potential risk of falls³.

Even in back-to-sit (BackTS) tasks, these are important issues. The BackTS task requires moving in a backward direction while facing forward, contacting the body (buttock) to an external environment (seat surface) while moving in a downward direction. In terms of motor planning processes, the central nervous system (CNS) has to estimate the gravito-inertial forces and also variables about chair property while compensating for the absence of visual feedback. If misjudgment occurred, it could increase the risk of falls. Previous studies about BackTS tasks have been more limited than those about sit-to-stand (SitTS) tasks³. No study has examined the effect of perception of chair property on BackTS movement yet.

As the first study about perception of chair property, our purpose was to investigate whether trajectory formation in the BackTS task is dependent on seat width information. Considering the relationship of the speed-accuracy trade-off⁴, when...
sitting into a narrower seat compared to their own hip breadth, participants may feel a need to “take care” and the motor strategy of BackTS movements would vary to be more careful. However, it is common for both healthy and older adults to sit on chairs such as a back chair with armrests or a wheelchair in daily activity but not often in extremely large or small chairs. The width of a wheelchair is up to 70 cm as per the Japanese Industrial Standards\(^5\). The usual seat width of a regular chair and of a wheelchair seems likely to be only about 40 cm (from 30 cm to 50 cm). Motor strategy may not vary, in preference for efficiency, since participants are already used to the variability of seat width used daily and feel safe with these variations. Therefore, we hypothesized that regardless of awareness of seat width, the trajectory formation in BackTS task would be invariant within the range of seat width used in a daily environment.

**PARTICIPANTS AND METHODS**

Ten young males (age: 22.3 ± 2.8 years, height: 171.3 ± 6.1 cm, and weight: 65.8 ± 7.9 kg) were recruited for the study. We obtained signed consent after explaining the study procedure in detail to all participants. The study was conducted with the approval of the Tohoku Bunka Gakuen University ethical committee (No. 18-06).

Figure 1 shows the characteristics of the chair apparatus and sitting posture used for measurements in the study. Hip breadth was measured based on parameters from the International Organization for Standardization\(^6\). It was measured as the length between the two greater trochanters in a sitting posture, which was then defined as the 100% seat width condition. There were 5 seat width conditions in the study. The mean of seat widths used in the study were 27.6 cm, 31.0 cm, 34.4 cm, 37.9 cm, and 41.3 cm (w80%, w90, w100%, w110% and w120%, respectively).

The study protocol was a sequence of SitTS tasks, BackTS tasks, and a questionnaire for each seat width condition. The questionnaire was administered in a separate room. The questionnaire consisted of one question: “How do you feel regarding the seat width compared with your hip breadth?” The five options for answering were (1) narrow, (2) a little narrower, (3) normal, (4) a little wider, and (5) wide.

Reflective markers were placed at both sides of the acromion process, the anterior superior iliac spine, the greater trochanter, the lateral femoral, the lateral malleolus, and the fifth metatarsal head. Each marker position was recorded using a six-camera motion analysis system (Locus 3D MA-5000; Anima Corp, Japan) at a sampling frequency of 250 Hz. The vertical, anterior–posterior, and lateral (z-, x-, and y-axis, respectively) components of the floor reaction force (FR) were collected at 250 Hz.

Kinematic data were converted into 101 data points using a spline function. For data processing, we used an original program written in MATLAB (R2007b, The MathWorks, Inc.). Marker positions data were low-pass filtered with a cutoff frequency of 5 Hz for smoothing. The center-of-gravity (COG) was calculated from Winter’s reference data\(^7\). Analyzed data were defined from the COG velocity exceeding 5% of its peak value to the COG velocity being less than 5% of its peak value, and the period was calculated as the time duration in seconds. As spatial features, the COG displacement and velocity profiles

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**Fig. 1.** Determining the sitting posture on the chair apparatus when starting the sit-to-stand (SitTS) task and when ending the back-to-sit (BackTS) task.

The sitting posture on the wooden seat surface (seat depth: 40 cm) for each task is described in terms of 4 determinations. (1) The yellow dashed line indicates that the back edge of the anterior–posterior (a–p) base of support (BOS) is defined as zero [cm] in the a–p direction. Thus, it shows a negative value when center-of-gravity moves backward (COG over BOS). (2) The distance between the front edge of the chair and the yellow dashed line is defined as 40% of the thigh length. (3) The seat height is set to the vertical length between the fibula head and the floor surface. (4) The target line (black dashed line) is used to indicate the correct buttocks position in the a–p direction and determines the beginning of the SitTS task and the end of the BackTS task in the same buttocks position.
were averaged for all participants. The mean COG velocity [m/s] from onset time to on-seat time was also calculated for each movement direction. Each temporal variable (COG change direction, COG over BOS, and on-seat time) were calculated as relative to time [%time]. The FR peak value [%weight] on the chair apparatus side was calculated as an index of the impact force. Also, the buttocks’ contact position against the seat surfaces was measured to examine whether participants were able to sit-down with their buttocks in the correct position under different seat width conditions. The buttocks’ contact position was calculated using the difference between reflective marker positions of the greater trochanter at the beginning of the SitTS task and at the end of the BackTS task (Fig. 1).

All data were analyzed using R, version 3.4.1. Repeated-measure analysis of variance was performed with each dependent variable, and with seat width conditions as the independent variable. When the main effect was significant, post-hoc comparison was performed using the Sheffer method. A p value of 0.05 was considered significant.

**RESULTS**

The difference of the buttocks’ contact positions between the SitTS and BackTS tasks was 0.64 ± 1.58 cm (range: −2.57 to 4.97 cm) in the anterior–posterior (a–p) direction and −0.19 ± 1.53 cm (range: −4.27 to 2.43 cm) in the lateral direction for all participants. These buttocks positions were shown to be within the mean ± 3 SD of all measurements in each direction, and participants were able to sit down in a relatively specific buttocks position under all seat width conditions.

The results of questionnaire (Table 1) showed that the most common answers in the w80% and w90% conditions were “narrow” or “a little narrower”, respectively (50% of all participants). In the w100% condition the most common answer was “normal” (40% of participants). In the w110% and w120% conditions the most common answers were “a little wider” or “wide”, respectively (50% and 60% of all participants).

The averaged COG displacement and velocity profiles for each movement direction were invariant for each seat width condition (Fig. 2). Additionally, the temporal variables, the COG change direction time (F[4, 36]=0.97, p=0.44), COG over BOS time (F[4, 36]=0.7, p=0.60), and on-seat time (F[4, 36]=0.57, p=0.69) were not significantly different with respect to the seat width conditions. Also, the duration time (F[4, 36]=1.09, p=0.38), COG mean velocity (in vertical direction; F[4, 36]=0.26, p=0.90, in a–p direction; F[4, 36]=1.80, p=0.15) and FR peak value (F[4, 36]=2.51, p=0.06) showed no significant effect related to the seat width conditions.

| Table 1. Results of questionnaire for each seat width condition | (n=10) |
|---------------------------------------------------------------|-------|
| w80%  | w90%  | w100% | w110% | w120% |
| Narrow | 5     | 3     | 0     | 0     | 0     |
| Little narrow | 3     | 5     | 3     | 0     | 0     |
| Normal | 1     | 1     | 4     | 3     | 0     |
| Little wide | 1     | 1     | 2     | 5     | 4     |
| Wide   | 0     | 0     | 1     | 2     | 6     |

The questionnaire comprised one question: “How do you feel regarding the seat width compared with your hip breadth?” and was administered in a separate room after the sit-to-stand and back-to-sit tasks. Participants were required to answer from five options on the paper questionnaire: (1) narrow, (2) a little narrower, (3) normal, (4) a little wider, and (5) wide.

**Fig. 2.** The center-of-gravity (COG) displacement and velocity profiles in the back-to-sit task for each movement direction and seat width condition.
DISCUSSION

We investigated the effect of perception of seat width on BackTS task in healthy adults. According to the questionnaire results (whether participants recognized the seat width compared to their hip breadth), many participants were aware of the difference between the width of the seat and the size of their body but some participants were unaware (Table 1). Nevertheless, the averaged spatial and temporal variables were invariant under different seat width conditions (Fig. 2) and all participants were able to correctly carry out the task without falling. These results supported our hypothesis.

In previous studies about BackTS tasks, older adults used a different strategy compared to healthy adults with increased duration time and a different trunk orientation angle. On the other hand, Mourey et al. studied the effect of visual conditions (light and darkness) on BackTS tasks in healthy and older adults. They revealed that the absence of visual information did not influence duration time of sitting-down performance in either group. We learned two things from this previous study. First, surprisingly, the BackTS task may not be a so-called more careful performance but rather a ballistic performance. Second, if participants already have information about chair properties, motor strategy in BackTS task is not varied according to the task demands. Therefore, we considered that the movement trajectory in BackTS task is formatted for preferring “efficiency” over “safety” under the variability of seat width used in daily situations (mean 27.6 cm in w80% to 41.3 cm in w120%). It may be suggested that difficulties in sitting down for older adults can be attributed to other chair property information (e.g. backrest, armrest and seat material) in addition to physical decline.

On the other hand, grasp tasks are very similar to BackTS tasks in that one’s own body (finger or buttocks) contacts an external environment (targets or seat). In a study of grasp tasks, temporal kinematics was invariant under different target sizes, supporting our invariant results for the BackTS task. This is because, the CNS has adapted for various external environment or task demands by using a simple rule. We concluded that the trajectory formation in BackTS task was not dependent on the perception of seat width information.

One limitation of this study was not including elderly adults. Also, we did not consider the effects of other chair properties. Therefore, we consider it necessary to further investigate with these parameters included.

Conflict of interest

None.

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REFERENCES

1) Robinovitch SN, Cronin T: Perception of postural limits in elderly nursing home and day care participants. J Gerontol A Biol Sci Med Sci, 1999, 54: B124–B130, discussion B131. [Medline] [CrossRef]
2) Sakurai R, Fujiwara Y, Ishihara M, et al.: Age-related self-overestimation of step-over ability in healthy older adults and its relationship to fall risk. BMC Geriatr, 2013, 13: 44. [Medline] [CrossRef]
3) Durward BR, Baer GD, Rowe PJ: Functional human movement: measurement and analysis. Butterworth-Heinemann, 1999.
4) Schmidt RA, Zelaznik H, Hawkins B, et al.: Motor-output variability: a theory for the accuracy of rapid motor acts. Psychol Rev, 1979, 47: 415–451. [Medline] [CrossRef]
5) JIS T 9201: 2016. Manually propelled wheelchair. https://www.jisc.go.jp/app/jis/app/Gnd/JSISearch.html
6) ISO 7250: 1996. Ergonomics, Basic human body measurements for technological design. https://www.iso.org/home.html
7) Winter DA: Biomechanics and motor control of human movement, 2nd ed. New York: John Wiley & Sons, 1990.
8) Mourey F, Pozzo T, Roulhier-Marcer I, et al.: A kinematic comparison between elderly and young subjects standing up from and sitting down in a chair. Age Ageing, 1998, 27: 137–146. [Medline] [CrossRef]
9) Dubost V, Beauchet O, Manckoundia P, et al.: Decreased trunk angular displacement during sitting down: an early feature of aging. Phys Ther, 2005, 85: 404–412. [Medline] [CrossRef]
10) Wallace SA, Weeks DL: Temporal constraints in the control of prehensile movement. J Mot Behav, 1988, 20: 81–105. [Medline] [CrossRef]
11) Marteniuk RG, MacKenzie CL, Jearnerod M, et al.: Constraints on human arm movement trajectories. Can J Psychol, 1987, 41: 365–378. [Medline] [CrossRef]
12) Gordon J, Ghilardi MF, Cooper SE, et al.: Accuracy of planar reaching movements. II. Systematic extent errors resulting from inertial anisotropy. Exp Brain Res, 1994, 99: 112–130. [Medline] [CrossRef]