Quantitative evaluation of subjective posture recognition by physiotherapists using a 3D motion capture

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Abstract. [Purpose] This study evaluated subjective posture recognition by physiotherapists with expertise in posture, examined the quantification of posture using a three-dimensional (3D) motion capture, and described posture-based characteristics. [Participants and Methods] We photographed good, normal, and bad postures in 12 participants using an infrared camera, and the resultant data were analyzed. [Results] We observed the largest displacement from a good to a bad posture in the tenth thoracic vertebra on the X-axis in the anterior–posterior direction in comparison with other index points. Further, we observed considerable differences between good and bad postures compared with other index points. Moreover, we noted significant differences between the amount of displacement between good to a normal posture and from a good to a bad posture. The vertical displacement of the Z-axis was smaller than other index points. [Conclusion] Th10 captured features from the three postures. The X-axis was displaced most between good and bad postures. Further, the amount of displacement on the Z-axis was less between good and bad posture, rendering it difficult to capture features. Therefore, the findings reported herein can be used to compare the front and rear directions of the X-axis for capturing postural changes.

Key words: Posture recognition, VICON, Posture evaluation

INTRODUCTION

In recent years, the amount of time Japanese people spend sitting has increased, with 55–60%, or 420 min, of daily living time (excluding sleep) being spent in a seated position, which is the longest in the world1). Changes to living and working environments have promoted lifestyles centered around sitting and lack of activity. It is likely, therefore, that secondary factors will lead to an increase in morbidity.

Most posture evaluations are based on objective indices. There are definitions for mechanical, physiological, medical, psychological, aesthetic, and working postures2). Medical evaluations may indicate that morbid or abnormal posture is due to disease. Such posture is unnatural and inefficient, resulting in increased energy expenditure due to unnecessary muscle activity3). For this reason, the influence of posture on the body gradually increases and may ultimately cause pain if a healthy person lacks awareness of their bad posture. In terms of preventing negative effects of posture on the body, the correct recognition and improvement of deportment is essential.

The Ministry of Health, Labor, and Welfare has provided “Guidelines for the prevention of back pain in the workplace” in response to problems arising from bad posture4). To maintain a posture that places fewer burdens on the body, the lumbar
spine should work in a posture that maintains lordosis, with movement, but not kyphosis, which renders the spine defenseless to injury. Similarly, the Japanese Association of Physical Therapists\(^5\) works with people to promote self-management and exercise to prevent back pain.

Prior studies have reported objective evaluations of posture but there is little evidence of subjective posture evaluation on the part of the subject followed by objective posture evaluation based on it. Previously, we conducted a questionnaire-based survey of university students studying physiotherapy and occupational therapy\(^6\) and current physiotherapists\(^7\) to examine subjective posture recognition. The results suggested that about 80% of both standing and sitting postures were bad and sitting posture was worse than standing posture. We examined which part of the body was most associated with bad posture, based on the line of the center of gravity, and found that posterior displacement of the back of the chest had the greatest affect.

In addition, chair-based seated posture was quantitatively analyzed using a three-dimensional motion analyzer. We, therefore, compared the displacement of the 10th thoracic vertebra (Th10) in 12 physiotherapy students\(^8\). These students did not recognize their normal posture as a good posture.

The purpose of this research is to analyze the amount of displacement from a good posture to a bad posture by a physiotherapist with postural expertise using a 3D motion capture. In particular, the purpose of this study is to investigate the effects of the back indicated in the preliminary survey using Th10 index points. The objective is also to compare a good posture and a bad posture to show a characteristic distinction. Furthermore, this study aims to compare whether the normal posture is associated with good or bad posture. Therefore, clarifying whether the subject’s own posture can be evaluated objectively is necessary.

**PARTICIPANTS AND METHODS**

The participants were 12 physical therapists who each had more than 2 years of experience and no orthopedic diseases (age 25.8 ± 1.4 years, height 175.4 ± 5.2 cm, weight 67.0 ± 8.0 kg, BMI 21.8 ± 2.2, years of experience 3.5 ± 1.4). The purpose of the research, experimental content, and ethical considerations were explained in advance, and the participants provided written consent. This research was approved by the ethical committee of Gunma University of Health and Welfare (approval number: 18A-22) in accordance with the Declaration of Helsinki.

Measurements were obtained in the motion analysis room of the Department of Rehabilitation, Gunma University of Health and Welfare. A motion capture system (VICOM Nexus 2.7.0) was used for 3D motion analyses. Seven infrared cameras were used for shooting, and the sampling frequency was 100 Hz. The camera was installed near the ceiling so that the participant was in the center of the image. Furthermore, reflective markers (each 14 mm in diameter) were attached to the body of the participant with reference to Plug-in Gait Full Body AI.

**Figure 1** shows the participant’s clothing (shorts and swimming cap) and reflective marker locations. Photography was initiated after confirming with two measurers whether the camera was affixed at the appropriate designated location. The sitting posture in the chair was set to 90 degrees at the knee joint and 0 degree at the ankle joint using a University of Tokyo goniometer\(^9\). The contact position of the sole was measured at the midpoint of the heel by determining the distance between the left and right upper anterior iliac spines. As a precaution before the measurement, we instructed the sitter not to move the sole or buttocks and did not give the participant any information about the quality of their posture. Before shooting, we told the participants to shoot in the order of good, normal, and bad postures. In addition, each posture was left to the participant’s subjectivity. At the time of imaging, each posture was changed according to the instructions of the examiner. The examiner checked with the participant whether it was acceptable to start shooting in each posture and started shooting.

As shown in **Fig. 2**, the chair sitting posture was measured once for about 5 s each for good posture (Good), normal posture (Normal), and bad posture (Bad). Data from the start of measurement up to 2 s was used. The time required per person was about 60 min. From 0 to 20 min, the contents of the study and the shooting procedure were explained and the body of the participant was habituated to the measurement environment. For 20–40 min, the participants changed into the prepared clothes and affixed reflective markers. For 40–60 min, physical information such as height, weight, and limb length were provided as input and each posture was photographed.

Eight points were used to examine the features of the postures: the 7th cervical vertebra (C7), thoracic fold (CLAV), xiphoid process (STRN), Th10, pelvic part of upper right anterior iliac spine (RASIS), left upper anterior iliac spine (LASIS), upper right posterior iliac spine (RPSIS), and upper left posterior iliac spine (LPSIS). The coordinate values of the markers obtained from each posture were input to Excel\(^{TM}\) for analysis. As shown in **Fig. 2**, data were collected to be used as x and z coordinates. The x coordinate was the forward and backward movement and the z coordinate was the vertical movement. Next, the amount of displacement in the forward and backward directions and vertical direction was calculated based on good posture (0 mm). The forward movement of the x coordinate was plus (+), the backward movement was minus (−), the upward movement of the z coordinate was plus (+), and the downward movement was minus (−).

During the pre-investigation it was found that the back had the most effect on posture. Therefore, we compared the three postures using the Th10 marker on the back to see how much it was affected. The same comparison was made for C7, RPSIS, and LPSIS on the back and CLAV, STRN, RASIS, and LASIS on the abdomen. In the analysis, the displacements from the good posture to the normal posture and from the good posture to the bad posture were obtained. Next, the analysis of variance by repeated measurements was performed, and changes in the X and Z coordinate values from the origin in the participant’s
subjectively good, normal, and bad postures were confirmed. When the main effect was significant in the analysis of variance by repeated measures, a multiple comparison method was used as a post-hoc test. Differences were considered significant if the p value was <0.05. All statistical analyses were conducted using a commercially available statistical software (BellCurve for Excel (Ver. 3.20), Social Survey Research Information Co, Ltd., Tokyo, Japan).

Fig. 1. Positions of reflection markers indicates the reflective marker used in the analysis.

Fig. 2. Three chair sitting postures.
RESULTS

Table 1 presents the amount of displacement seen between good and bad postures. In the forward and backward direction, large displacements, 88.3 ± 49.5 mm for the ventral STRN and −89.2 ± 43.1 mm for the dorsal Th10, were measured. Most points, except C7, were displaced backward. However, there were individual differences. Next, in the vertical direction, the largest displacement was found for the ventral CLA V (−76.4 ± 29.3 mm), followed by the STRN (−73.4 ± 28.6 mm). On the dorsal side, the RPSIS was displaced by −51.2 ± 23.1 mm and the LPSIS by −50.9 ± 22.8 mm. The vertical movement was generally downward. The Th10 was greatly displaced backward in the front-rear direction but slightly displaced downward in the vertical direction.

Analysis of variance by repeated measurement was performed using X and Z coordinate values based on the origin. Table 2 shows the results of the Friedman test. The X coordinate showed a significant difference (p<0.01) between STRN, RASIS, LASIS, C7, Th10, RPSIS, and LPSIS. In the Z coordinate, there was a significant difference (p<0.01) between CLAV and STRN, C7, RPSIS, and LPSIS, and there was also a significant difference (p<0.05) in the observed Th10. This indicates that there were differences in the vertical coordinate values of the three poses. Th10, the focus of this study, showed a significant difference in each coordinate value.

Next, Table 3 shows the results of the multiple comparison method. As a result of Scheffe, there was a significant difference of p<0.01 in all combinations of good and bad postures at the X coordinate index points. The other combinations showed a significant difference of p<0.05. In the Z coordinate, Th10 showed a significant difference (p<0.05) between good and bad postures, but not with other combinations (p>0.05).

DISCUSSION

The aim of this study was to evaluate subjective posture recognition by a physiotherapist with postural expertise, examine quantification of posture using a 3D motion capture, and explain posture-based characteristics.

The results of a questionnaire by Shingai suggested that Th10 was most affected in bad posture6. Hence, the displacement of the Th10 was examined. The Th10 showed the most displacement at the CLAV, STRN, C7, Th10, RPSIS, and LPSIS points. The results of both the subjective questionnaire and the motion analysis suggested that displacement of the Th10 is significant to posture.

In the comparison of the three postures in the front-rear direction at the index point of Th10, significant differences were found in all combinations based on the analysis results based on the combinations.
This indicates that there is a difference between recognition of good posture and bad posture. The normal posture did not show any significant association with both the good posture and the bad posture.

In other words, although physiotherapists know about good posture, since maintaining a good limb position for a long time causes fatigue, it can be inferred that a posture which leads to less fatigue (a so-called easy posture) is more often selected. However, bad posture (thoracic kyphosis, lumbar kyphosis, or leaning forward with pelvic tilt) reduces muscle activity compared with good posture (upright trunk), the pressure on passive components is likely to increase, and the internal pressure of the intervertebral discs may also increase.

Tokutake et al. investigated the use of backpacks (knowledge of and preference for) among university students who had a certain knowledge of the mechanism of back pain and understood the differences in the burdens placed on the body due to the use of backpacks. Nevertheless, they report that most consideration was given to preference for backpack use. They pointed out that future health education aimed at preventing back pain should include more than just the knowledge of prevention.

Based on the points described above, further research is needed to clarify the reason why posture is generally not good. However, based on the results of subjective posture recognition, objective posture analysis appears to be necessary. According to displacement in the Z-axis, it was difficult to grasp the quality of the posture. Furthermore, this is the first study to explain the usefulness of displacement from good posture to bad posture based on the variation of Th10 on the X-axis. In addition, it was suggested that the relevance could be known by comparing the three postures. Future studies will compare these results with physiotherapy students. It is also necessary to compare the three groups after obtaining the answers in advance about the posture felt by the participant.

In addition, the three groups should be compared with regard to differences in the participant’s knowledge of posture. This study was prepared based on the results presented at the 28th International Congress of the Physical Therapy Science Association and the 5th Korean Society of Integrative Medicine.

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**Conflict of interest**

There are no conflicts of interest to be disclosed by the first author and coauthors regarding this paper.

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