

## Is it possible to apply the TUG test and accelerometer data to diagnose early hip osteoarthritis?

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**INTRODUCTION:** The prevalence of hip osteoarthritis (hip OA) is estimated at one in four persons and its incidence tends to increase with age. Gait retraining in early-stage OA has been reported to slow disease progression in hip OA patients [Eitzen I: 2015]. This requires the development of diagnostic criteria for early-stage hip OA [Runhaar J: 2021]. However, there is still no useful methodology for accurately diagnosing early-stage hip OA using gait to provide functional and anatomical information. The present study focused on the timed up-and-go (TUG) test, including standing up from a chair and walking around a cone 3 meters away. The TUG test in accelerometer-wearing subjects not only provides detailed analysis of gait and movement, but might also allow comparison of hip OA progression. We examined the possibility of objectively detecting early-stage hip OA from both behavioral information in the TUG test and accelerometer data.

**METHODS:** The subjects included 36 hip OA patients undergoing their first medical examination or follow-up examination at the department of orthopedic surgery of Iwate Medical University Hospital and Morioka City Hospital. Based on the Kellgren-Lawrence (KL) classification, anterior X-ray images of the hip joints bilaterally were used for diagnosing the disease stage of hip OA. Hip disability and osteoarthritis outcome score (HOOS) was used for functional evaluation of hip OA patients. In all subjects, a wireless accelerometer was directly fixed to the skin over the spinous process of L3 during the TUG test. The number of steps taken during the TUG test and the time for each movement were measured by dividing the movement into components based on up and down movement data in the accelerometer. The sampling period of the acceleration data was 2.5 seconds before and after turning the cone, for a total of 5 seconds (Fig. 1). A composite vector scalar product (CV) was created by synthesizing acceleration in all three directions. The CV data were used to calculate a distribution of acceleration histogram in order to compare each group (Fig. 2B). Significant differences between groups were calculated using ANOVA, with a value of  $P < 0.05$  indicating statistically significant differences for all analyses.

**RESULTS:** Radiographic images were classified based on the KL classification system, with all KL-2 patients considered as early hip OA (e-hOA), all KL-3 patients as moderate hip OA (m-hOA), and all KL-4 patients as severe hip OA (s-hOA). Hence, patients were divided into four groups, including a healthy group. Detailed patient information is shown in Table 1. Compared to healthy subjects, the time for accomplishing the TUG test tended to be prolonged in all the hip OA patients. The number of steps counts during passing through the cone tended to decrease with increasing severity of OA. Movement in the TUG test was divided into three stages: sitting to standing before walking, walking, and standing to sitting, and the time for each stage was measured (Fig. 2A). With the progression of hip OA, the time for each movement was prolonged. A comparison of CV histogram distributions showed a slight increase in the small acceleration distribution ( $1-3 [m/s^2]$ ) in e-hOA and m-hOA compared to healthy subjects (Fig. 2B). On the other hand, there was clear increase in the large acceleration ( $7-8 [m/s^2]$ ) frequency in s-hOA compared to healthy subjects. There was a significant difference in HOOS among the three OA groups. A statistically significant difference in histogram distribution between the four groups was also confirmed (ANOVA,  $p < 0.001$ ).

**DISCUSSION:** The gait of patients with early hip OA is visually indistinguishable from that of healthy individuals. However, the duration of each movement in early OA was longer than that in the healthy group. Furthermore, there was a tendency for the duration of each movement to remarkably increase as hip OA progressed. It is highly possible that the extension of each movement time is strongly related to the walking speed during walking around the cone (Fig. 2A). Therefore, it is necessary to consider the acceleration data when walking around the cone in the analysis and compare it between hip OA stages. Statistically significant differences were observed among the four groups in the TUG task execution time, each movement time, and acceleration analysis (Fig. 2 and Table 1). In the CV histogram distribution, the frequency of small acceleration vectors increased significantly in the e-hOA group as compared to the healthy group. This suggests that the signs of attentive gait seen in m-hOA patients may already be present in e-hOA patients. The increase in frequency of large vector values in the s-hOA group (Fig. 2) could be attributed to the increased variation in longitudinal acceleration of gait in the s-hOA group (figure not included in the abstract). This suggests that analyzing the progress of hip OA by combining TUG and acceleration data is effective for the early diagnosis of OA, and that detailed information can be obtained by combining the TUG test with conventional X-ray diagnosis.

**SIGNIFICANCE/CLINICAL RELEVANCE:** (1-2 sentences): Globally, the prevalence of hip OA is showing an increasing tendency. Considering the patient's quality of life, research on delay in the progression of OA by its early detection and intervention is positioned as "important research" from the perspective of clinical relevance and the clinician's viewpoint.

**REFERENCES:** Include references here. (References are Optional)

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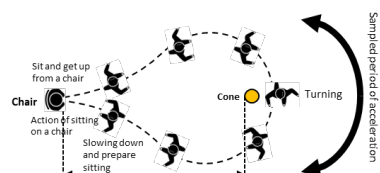


Figure 1. Overview of the TUG test. Video and acceleration data were simultaneously recorded during TUG execution, from which it was possible to identify the subject's movement. The analyzed acceleration data were sampled before and after walking around the cone (thick black line).

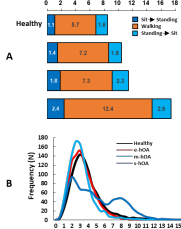


Figure 2. A: Comparison of each behavior time and KL grade during the TUG test. B: Histogram of composite vectors in the KL grade groups.

Table 1. Subject information, time duration of timed up-and-go (TUG), and step counts, as obtained from accelerometer data.

Group	KL Grade	N	Mean $\pm$ SD				
			Age	BMI	HOOS	TUG time	TUG Steps <sup>a</sup>
Healthy	-	22	40 $\pm$ 9	21.3 $\pm$ 2.2	-	8.8 $\pm$ 0.6	10.3 $\pm$ 0.4
e-hOA	2	15	56 $\pm$ 19	21.1 $\pm$ 1.6	88 $\pm$ 9	9.9 $\pm$ 1.5*	9.9 $\pm$ 1.7
m-hOA	3	10	58 $\pm$ 13	21.1 $\pm$ 1.6	56 $\pm$ 18	10.2 $\pm$ 2.7	9.1 $\pm$ 1.5
s-hOA	4	11	66 $\pm$ 6**	26.1 $\pm$ 4.7**	34 $\pm$ 14	17.3 $\pm$ 6.9**	7.6 $\pm$ 17.3*

KL Grade: Kellgren-Lawrence Grade. BMI: Body Mass Index (WHO). HOOS: Hip Disability and Osteoarthritis Outcome Score (Klassbo M, et al., 2003 and Nilsdotter AK, et al., 2003). TUG: Timed Up & Go Test. \*/\*\* : vs healthy subjects  $p < 0.05$  /  $p < 0.01$ . a: The number of steps during 5 seconds before and walking around the cone. This was counted using the peak numbers of vertical movement data. ###: ANOVA  $P < 0.001$ .