GYENNO MATRIX Gait Parameter Validation Instructions

Abstract

Background:

GYENNO MATRIX is a wearable motion evaluation device comprising 10 MEMS inertial sensor nodes, a data center and corresponding upper computer software. The subject wears sensor nodes to perform designated motion evaluation according to specifications, sensor data will be transmitted in real time to upper computer software through the data center, and upper computer software will process and calculate human gait parameters. This article mainly describes how to use measurement tools (ruler, stopwatch and so forth) to measure some parameters of motion evaluation test, and apply this as a golden standard to compare with GYENNO MATRIX calculation results and validate accuracy of GYENNO MATRIX evaluation results.

Method:

13 healthy subjects have been recruited to wear GYENNO MATRIX nodes respectively and complete the designated motion evaluation test according to specifications, relevant characteristic parameter measurement results are available by ruler measurement and video marking in late period, measurement results are compared with GYENNO MATRIX software calculation results, and LCC and RMSE statistical indexes are adopted to evaluate the accuracy and consistency of GYENNO MATRIX calculation results.

Conclusion:

The results show that GYENNO MATRIX has higher accuracy and consistency for the validated parameters, and the results of motion evaluation test calculated by GYENNO MATRIX are more convincing.

Keywords:

Wearable device, motion evaluation, consistency, accuracy;

Subject Information

Select 13 healthy subjects, aged 25-37, including 9 males and 4 females, all of whom fall in the height range of 155cm-180cm. See Table 1 for information on the thigh and calf length.

No.	Gender	Height (cm)	Thigh Length (cm)	Calf Length (cm)
1	Male	163	49	42
2	Male	166	43	46
3	Female	159	46	44
4	Male	178	53	50
5	Male	175	50	46
6	Male	174	49	47
7	Female	168	48	46
8	Male	174	48	48
9	Male	173	48	46
10	Male	177	50	49
11	Female	155	45	43
12	Female	170	50	43
13	Male	172	50	44

Table 1-Subjects Information Table

Validation Method

The subjects are requested to perform “7m Timed Up and Go ” (TUG) test in a room of no less than 4m x 7.5m at different times. TUG test process is: stand up -> walk straight -> turn 180 degrees -> walk straight -> turn 180 degrees -> sit down. (As shown in Figure 1).

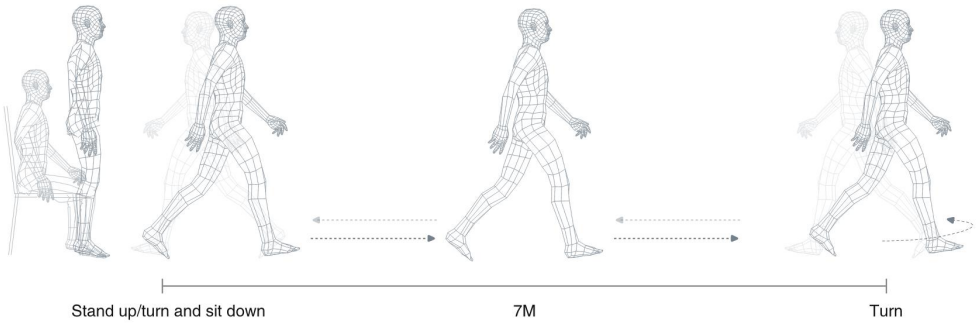

Figure 1-“Timed Up and Go” test Process Diagram

Before the test, subjects must wear GYENNO MATRIX straps and nodes correctly, and the center of their shoe sole strap is fixed with a red mark dot with a diameter of about 10mm, so that they will leave red mark on the ground every step of the way. The camera is set in the middle of one end of the room, and the shooting angle of camera is adjusted to ensure the camera can fully capture the subjects’ body movements throughout the TUG test (as shown in Figure 2), the video recording frame rate is about 30 frames/s, and GYENNO MATRIX’s upper computer software will print absolute time stamp mark in each frame of recorded video

(as shown in Figure 3).

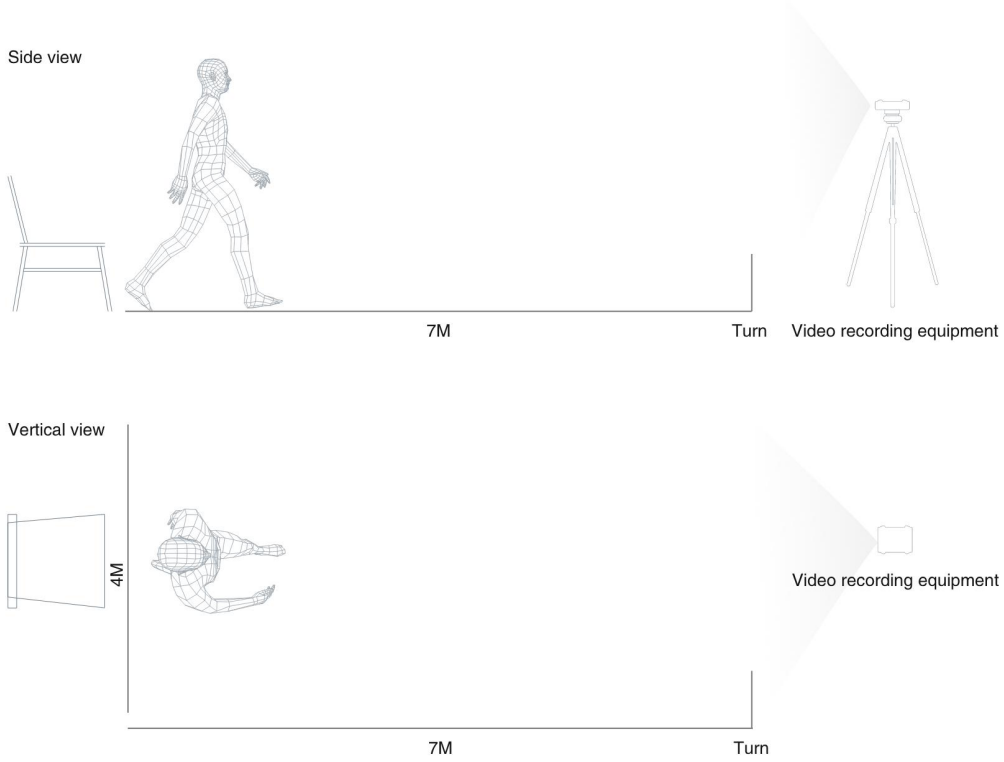

Figure 2-Test Site Layout

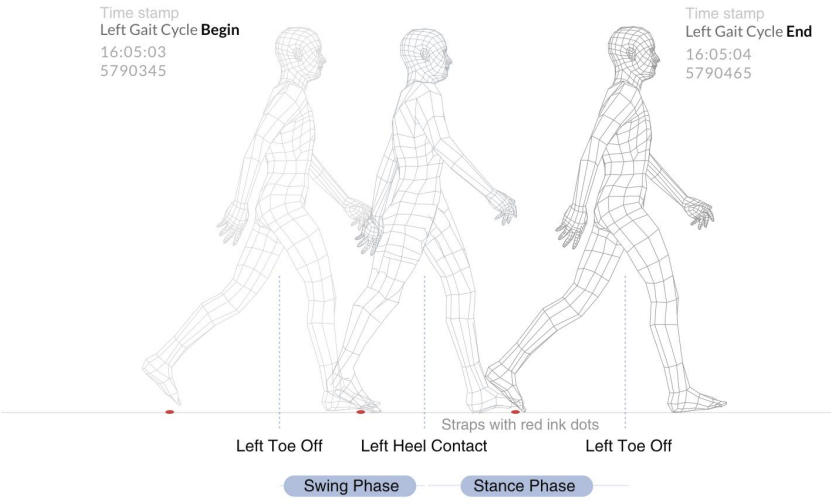

Figure 3-Test Video Recording Example

After the test is completed, use a ruler to measure the length between red marks left by the left and right foot (as shown in Figure 4), namely actual step length and stride length information, and use PotPlayer software to view the recorded movement video and mark the time stamp information of gait events such as heel-contact event and toe-off event frame by frame.

Eventually, record the marked gait events, step length and stride information in sequence. Then we use these gait events as basis to calculate parameters of gait cycle,swing phase and stance phase.The gait cycle is the time interval between one heel-contact event and the next same foot heel-contact event ,one gait cycle can be divided into a stance phase and a swing phase(as shown in Figure 3).Swing phase refers to the interval between the toe-off event and the next heel-contact event of the same side foot,similarly, the stance phase refers to the time interval from the heel-contact event to the next toe-off event of the same foot.Meanwhile, GYENNO MATRIX calculates the corresponding gait parameters.

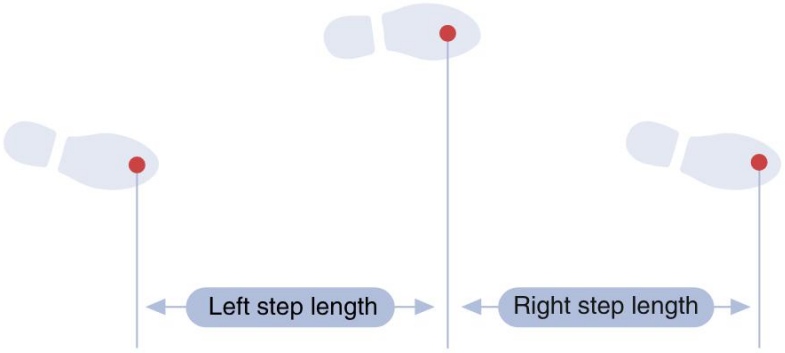

Figure 4-Step Length Measurement Diagram

Data Processing

Calculate the mean and standard deviation respectively based on each subject's step length, stride length, gait cycle, step frequency and other parameters acquired by measurement or video marking, and take such value as the reference value of parameters. Calculate the mean and standard deviation respectively based on the above corresponding parameters calculated by the GYENNO MATRIX algorithm. Lin's Concordance Correlation Coefficient (LCC) and Root Mean Square Error (RMSE) indexes to evaluate the reference value and GYENNO MATRIX parameter results, of which Lin's Concordance Correlation Coefficient (LCC) is used to compare the consistency of two measurement values for the same variable, and its formula is:

$$\mathrm{LCC} = \frac{2RS_xS_y}{\left(E_x - E_y\right)^2 + S_x^2 + S_y^2}$$

Among them, S_x and S_y are standard deviations of reference sample x and measurement sample y respectively, E_x and E_y are means of reference sample x and measurement sample y respectively, R is the Pearson correlation coefficient of two samples, and the closer LCC value to 1, the two samples have higher consistency;

The formula for root mean square error (RMSE) is:

$$\sqrt{\frac{1}{m}\sum_{i=1}^{m}(y_i - \hat{y}_i)^2}$$

Among them, y_i and $\hat{y}_i$ stand for reference value and measurement value of a variable

respectively. RMSE indicates the size of measurement error, the smaller its value, the higher measurement accuracy.

Validation Results

Statistical results of parameters are shown in Table-2. Among them, LCC results greater than 70% are good, and those greater than 85% are excellent. From the statistical results, it is shown that 14 out of 21 parameters are excellent, and the others are all performing well; meanwhile, it is shown that the root mean square error (RMSE) of each parameter is less than 10% of the reference value.

Parameters	Reference Value	Calculation Value	LCC	RMSE	Level
LStepLen	61.92	62.76	86.90%	2.804	Excellent
RStepLen	62.91	63.16	89.28%	2.567	Excellent
MStepLen	62.08	62.93	96.38%	1.852	Excellent
LStrideLen	125.33	124.20	87.01%	5.326	Excellent
RStrideLen	125.51	123.83	85.03%	5.693	Excellent
MStrideLen	125.38	123.97	87.29%	5.220	Excellent
LGaitCycle	1.16	1.16	96.99%	0.007	Excellent
RGaitCycle	1.16	1.16	99.31%	0.007	Excellent
MGaitCycle	1.16	1.16	99.64%	0.004	Excellent
LCandance	105.88	104.70	93.47%	3.139	Excellent
RCandance	105.87	104.45	94.95%	3.094	Excellent
MCandance	105.44	104.54	97.97%	1.915	Excellent
LDoubleSupport	22.76	21.76	79.69%	1.855	Good
RDoubleSupport	22.18	21.30	81.63%	1.735	Good
MDoubleSupport	22.47	21.52	81.74%	1.532	Good
LStance	60.98	60.04	80.60%	1.226	Good
RStance	60.33	60.49	77.19%	0.983	Good
MStance	60.63	60.25	87.83%	0.713	Excellent
LSwing	39.02	39.96	80.60%	1.226	Good
RSwing	39.67	39.51	77.19%	0.983	Good
MSwing	39.37	39.75	87.83%	0.713	Excellent

Table-2 Statistical Result Table of Gait Parameters