Examination of Reliability and Validity of Walking Speed, Cadence, Stride Length—Comparison of Measurement with Stopwatch and Three-Dimension Motion Analyzer—

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Abstract. To examine the validity and reliability of values measured with a stopwatch (SW) and a three-dimensional motion analyzer (3D), walking speed and gait cycle variables were measured for ten healthy young individuals. Participants were given two assignments as subjects of the experiment. Their first role was to walk on a 16 m track from end to end at a comfortable speed, and as data measurers their second role was to use the stopwatch method to measure the time and number of steps taken for other subjects to pass through the measurement section of the track. The measurement section was set up in the middle of the track, with 4 m distance for the 3D and 10 m distance for the SW method. While subjects were walking from one end of the track to the other, their gait was measured by both the 3D and the SW methods. Each subject performed the gait trial 10 times. Results: Strong correlations were obtained among the measured values, both with the SW method and the 3D method, and high reliability was confirmed. Variables of time and space such as walking speed, cadence, and stride length can be measured by a stopwatch within the range of ± 0.1 s. The validity of the stopwatch method is strong: it showed tight correlation with the 3D method, but gave slightly shorter temporal and spatial parameters than the 3D method. The conclusion is that the stopwatch method is sufficient for the measurement of walking speed in the clinical field.

Key words: Gait analysis, Measurement time method, Inter-tester reliability

INTRODUCTION

There have been many studies on gait analysis. Gait analysis can be divided into the following three types: observation-based gait analysis (OGA), video-based gait analysis (VGA), and instrument-based gait analysis (IGA). OGA is generally used in clinical settings and IGA primarily in...
Recently, in clinical settings, the efficiency and sustainability of walking have come to be evaluated along with gait. The time taken to walk 10 m at maximum walking speed (10mMAX)\(^1\), the distance walked in 6 minutes (6MD)\(^2\), and the physical cost index (PCI)\(^3\) represent the efficiency and sustainability aspects of walking. The 10mMAX is used to assess ability to walk. While a subject walks on a straight, flat track of 10 m length, the time and number of steps taken to walk the distance are measured. The data obtained is used to calculate variables of time and space, such as average walking rate, cadence, and stride length. The 10mMAX is used as an index of walking function recovery in stroke patients\(^4\), and it is also used for many patients as an index for predicting daily activity levels after discharge from hospital\(^5\).

The 6MD is utilized for healthy elderly people and patients with heart or respiratory disease as an index of the distance the patient can walk for 6 minutes on a flat surface. The PCI represents the relationship between the distance walked in a limited time (generally 3 minutes) and the difference in the individual’s cardiac rate between the resting and walking states. It is considered to be an index of the efficiency and sustainability of walking. The PCI is widely used for children, elderly people, and many patients with gait disorders to assess the effectiveness of walking sticks and prostheses and the efficacy of treatment techniques.

It is important to investigate the reliability and validity of the variables used for gait analysis, i.e., the data obtained. There are many comparative examples of 10mMAX abroad\(^6,7,8,9\), but to the best of our knowledge no researchers have evaluated the data obtained by using a stopwatch for 10mMAX measurement in Japanese subjects or have investigated the relevance of this data.

A three-dimensional (3D) motion analyzer is an instrument that measures the position of each part of the body in 3D space. There are two ways to identify target points: optical and magnetic. The former uses digital cameras, video cameras, and opto-electronic cameras, and the latter uses magnetic sensors. A “Session for the Review and Comparison of 3D camera Systems for Clinical Gait Measurement” was hosted by the Clinical Gait Analysis Forum of Japan in July 1999 to evaluate the precision of these instruments. The results of the discussions held during the session were issued as a report. The report said that, in terms of the precision of distance measurement, most of the instruments could measure targets generally with an error of 5 mm or less\(^10\). Although these instruments provide large amounts of data on human gait, they require appropriate siting and specific installation procedures. Furthermore, they are expensive, preliminary work must be performed to set them up for measurement, and a specified time is required to perform each analysis. Because of such constraints, these instruments have not yet been widely introduced into clinical settings.

In the present clinical situation, however, the need for evidence-based physical therapy practice is being advocated, and it is not enough to judge clinical effects only on the basis of conventional ‘feelings’ or a limited number of variables.

Therefore, we tried to examine the validity and reliability of values measured with a stopwatch (SW) and a three-dimensional motion analyzer (3D) through the walking speed and gait cycle parameters of ten healthy young individuals.

**METHODS**

The subjects were ten healthy young individuals who exhibited no locomotor abnormalities and consented to participate in the study (average age, 22.9 years; average height, 167.7 cm; average weight, 62.4 kg; sex, 7 males and 3 females). The subjects were students at a training school for physiotherapists and were screened before the experiment by Shinshu University’s Ethics Committee of Research Involving Human Subjects. There were two assignments: five students in the subject role walked along a track one at a time from end to end at a comfortable speed, and five students in the measurer role each simultaneously used a stopwatch to measure the time and number of steps taken for the student to walk through the measurement section. The roles were then reversed. A researcher (one of the co-authors of this study who has more than 30 years’ experience in the stopwatch method) using the stopwatch method participated in the study as the expert.

**Measurement site (Fig. 1)**

1. Walking track
   The walking track was placed in a 26 × 6.5 m room. The 16 m track was designed to include a 10 m measurement section, a 3 m entry section,
and a 3 m end section. The P-tiles (hard polystyrene tiles) laid on the track reflected infrared radiation diffusely distorting the signals sent to the 3D analyzer. To solve this problem, joint mats were spread on the tiles. Joint mats are about 1 m square and 1.5 cm thick and are made of urethane foam, but when a subject weighing 80 kg or greater stands on a mat it is compressed only by about 0.5 cm. Any number of mats can be joined in a jigsaw fashion. On the mats, vinyl tape 2 cm wide was used to mark the starting line, the line where SW measurement began, the line where SW measurement ended, and the finishing line. A space about 1.5 m wide was set up on one side of the track to enable the measurer using a SW to move alongside the track.

(2) Installation of 3D cameras and VTR cameras
An Eagle RT (Motion Analysis Co. Ltd.) was used to record gait motion with a mechanical measuring error of 1 mm or less. It is capable of recording targets by the synchronization of analog signals. Data sampling was carried out for 8 s at 100 Hz. Six 3D cameras attached to tripods were deployed in a space about 7 × 6 m (height: 2 m). The beam line was 4 m long, 2 m wide, and 1.9 m high and was laid along the middle of the track. The 3D cameras were wired to the body of the measuring instrument, which was placed in the corner of the room. Calibration was carried out according to the manufacturer’s manual before measurement. VTR cameras, which were installed obliquely behind the entry line, were connected to, and synchronized with, the 3D analyzer.

Method of measurement using stopwatch
Both stopwatch measurement and 3D measurement were carried out simultaneously. Subjects started walking from one end of the track to the other at a comfortable speed. The moment that part of the subject’s foot came into contact with the line where stopwatch measurement began, or touched the ground beyond the line, the five measurers were expected to start stopwatch measurement simultaneously and to count the number of steps. When the subject’s leading foot touched the ground over the line where the measurement was to end and their trailing foot within the measurement section left the ground, the measurers stopped measuring. The total number of steps included the step taken when the trailing foot left the ground at the end of the measurement section. The measurers read out the measured values for recording by the notetaker. Measurement was repeated 10 times for each subject. After the five walking subjects had finished the assignment, the five measurers swapped roles with them and the experiment was repeated. Stopwatch measurement was carried out only after the measuring had been practiced at least more than 10 times.

Recording and analysis of data by 3D cameras
The 3D cameras automatically started recording the subject in the 3D measurement section by pressing the start button at the moment the subject

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Fig. 1. Setting of walking track.
moved in front of the measuring point. 3D measurement was implemented concurrently with stopwatch measurement. Just like stopwatch measuring, it was repeated 10 times per subject. Data sampling was carried out at 50 Hz for 8 seconds. Shutter speed was set at 1 ms. Sampling initiation occurred when the subject had moved 1 to 2 m past the line where the stopwatch measurement started.

Markers were prepared by a technique modified from reference to the users’ manual for the Data Interface File Format (DIFF) (Ver. 1992.06) and the work of Perry. Markers were attached to the following 14 points: both acromia, the lateral surfaces of the distal ends of both upper arms, the distal ends of both forearms, both trochanters, both lateral femoral epicondyles, the posterior surfaces of both heel bones, and the ends of both the big toes.

Data was saved in data files by subject number and the number of data inputs. After all the experiments had been conducted, the data for each trial was extracted from the data files to confirm whether each marker had in fact represented the region of the body it was intended to mark. 3D images were then prepared.

3D images were matched with concurrently shot VTR images and corrected following the confirmation of heel contact and toe off. The positions in the coordinate system and the time were recorded and saved as manual calculation data.

Set-up of subject groups and data processing and statistics
(1) Data processing by the SW method
The group of five students who did the measuring first was called Unit A, and the second group was called Unit B. The combination of the data sets of Unit A and Unit B was called the “student dataset.” The maximum and minimum measured values were removed from the dataset, which was then called the “dataset with no maximum and minimum values.” A dataset obtained from measurement by the expert was called the “expert dataset.”

For the time and number of steps taken in the student dataset, the maximum and minimum values were marked for every trial to plot the frequency distribution by counting the student’s number of times.

The maximum and minimum values for each trial were removed from the student dataset. This dataset was called the “dataset with no maximum and minimum values.”

In the student dataset and the dataset with no maximum and minimum values, the mean and standard deviation for both the number of steps and the time required, as measured by five students in each trial, were obtained to calculate a coefficient of variation (COV). Differences were calculated by subtracting the minimum values from the maximum values, and then evaluated.

Average walking speed, average cadence, and average stride length were calculated for the student dataset, the dataset with no maximum and minimum values, and the expert dataset, using the average values for Units A and B and those measured by the expert.

(2) Data processing by the 3D method
After the 3D images had been prepared as described above, walking speed was calculated by using the cadence and stride length indicated (walking speed = cadence × stride length/2). This was called the automatic processing dataset. The gait cycle from heel contact to the next heel contact was observed through the VTR to confirm position coordinates and time, which were then used to calculate stride length and stride duration. From these values, walking speed (= stride length/ stride time × 60) and cadence (= 120/stride time) were calculated. The dataset processed from the right-foot gait cycle was called the right-foot calculation dataset, and that processed from the left-foot gait cycle was called the left-foot calculation dataset.

(3) Statistical processing
SPSS ver. 11.5 for Windows was used for statistical work. The inter-class correlation coefficient (ICC) was derived by using reliability analysis Method 2 from SPSS for each of the two measuring groups, which consisted of one student group and the expert. ICCs were derived by using reliability analysis Method 2 for six datasets: three stopwatch-based datasets (student dataset, dataset with no maximum and minimum values, expert dataset) and three 3D-datasets. One-way analysis of variance (ANOVA) was carried out to compare groups, and then a multiple comparison test (Tukey’s HDS test) was conducted for verification.

RESULTS

The expert measured the number of steps required for the 10 subjects to walk 10 m at a comfortable pace: the maximum and the minimum values were
19 steps and 13 steps, respectively; the mean and standard deviation were 16.3 ± 1.3 steps. Maximum and minimum times required were 10.28 s and 6.08 s, respectively; the mean and standard deviation were 7.66 ± 0.91 s. The maximum and minimum walking speeds (calculated by using the time required) were 98.68 m/min and 58.37 m/min, respectively; the mean and standard deviation were 79.4 ± 9.0 m/min. The maximum and minimum cadences were 148.6 steps/min and 106.0 steps/min, respectively; the mean and standard deviation were 128.8 ± 8.7 steps/min. The maximum and minimum stride lengths were 153.8 cm and 105.3 cm, respectively; the mean and standard deviation were 123.2 ± 10.0 cm. These values approximately correspond with those described in textbooks of kinesiology for healthy adults walking at a free speed12,13).

Table 1 shows frequencies of maximum and minimum values obtained by the student stopwatch method measurers. It was predicted that one measurer would obtain 10 maximum and 10 minimum values, a total of 20 occurrences. Measurer JO obtained these values least frequently (9 times) and measurer RM obtained them most frequently (28 times), followed by 27 times for TK. Other measurers obtained frequencies close to the predicted figures. The frequency table reveals that the measurers who obtained maximum values frequently were AO, YS, and TK, whereas those who obtained minimum values frequently were SW, JI, and RM. Thus, errors produced not only dispersion, but also bias. In such cases it would be necessary to review the measuring standards, educate inexperienced measurers, and retrain them through comparison with the expert’s results.

For the measurements taken by each Unit, the mean, standard deviation, maximum value and minimum value were calculated for the number of steps and the times measured by the five student measurers. The coefficient of variation (COV) was then derived from the mean and standard deviation and expressed as a frequency distribution that described the 100 trials by the 10 people. For the number of steps required, 77 trials (77%) had COVs of 0, 17 (17%) had COVs of 0.02–0.03, and 6 (6%) had COVs of 0.03–0.04. The actual margin of error was one step for 23 trials. For the time required, as few as 24 trials had COVs of less than 0.01, 49 had COVs of 0.01–0.02, accounting for 73% of COVs. Twenty-one trials had COVs of 0.02–0.03, and only 6 had COVs of more than 0.03. With regard to the time difference between the maximum and minimum values, 32% of trials had differences of less than 0.2 s and 76% had differences of less than 0.4 s. On the other hand, 24 trials had differences of more than 0.4 s. These results show that it is possible for marked errors to occur unless measurers have sufficient measuring skills (Fig. 2).

The number of steps required was reviewed in the way generally used for athletic races, which excludes the maximum and minimum value from the data. After the review, only five trials (5%) were found to have deviated. For the time required, 74 trials (74%) had COVs less than 0.01 s, 85% had COVs less than 0.02 s, and 100% had COVs less than 0.03 s. For the difference between the maximum and minimum values, 56% of trials had less than 0.1 s, 85% had less than 0.2 s, and 95% had less than 0.3 s. These results show that elimination of maximum and minimum values controlled dispersion and improved the precision of data, compared with the student dataset (Fig. 2).

Reliability was reviewed among six individuals: five students in Unit A and the expert. For the steps required, the intra-class correlation coefficient (ICC) was 0.968 (single rating, P<0.001), and the confidence coefficient α = 0.994. In the same way, the review of reliability among the other six individuals (five students in Unit B and the expert) gave an ICC of 0.945 (single rating, P<0.001) and α = 0.990. Thus, high reliability was exhibited for the number of steps required. In contrast, for the measured values of the time required, the results of the review of reliability showed that among six

<table>
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<tr>
<th>Testers</th>
<th>Max.</th>
<th>Min.</th>
<th>Total</th>
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<tbody>
<tr>
<td>JO</td>
<td>3</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>SK</td>
<td>3</td>
<td>15</td>
<td>18</td>
</tr>
<tr>
<td>KK</td>
<td>9</td>
<td>8</td>
<td>17</td>
</tr>
<tr>
<td>TY</td>
<td>12</td>
<td>9</td>
<td>21</td>
</tr>
<tr>
<td>MT</td>
<td>9</td>
<td>11</td>
<td>20</td>
</tr>
<tr>
<td>AO</td>
<td>15</td>
<td>6</td>
<td>21</td>
</tr>
<tr>
<td>JI</td>
<td>8</td>
<td>14</td>
<td>22</td>
</tr>
<tr>
<td>YS</td>
<td>21</td>
<td>2</td>
<td>23</td>
</tr>
<tr>
<td>TK</td>
<td>19</td>
<td>8</td>
<td>27</td>
</tr>
<tr>
<td>RM</td>
<td>2</td>
<td>26</td>
<td>28</td>
</tr>
<tr>
<td>Total</td>
<td>101</td>
<td>105</td>
<td>206</td>
</tr>
</tbody>
</table>

Data of the Testers includes 6 duplicated data.
measurers (Unit A + the expert) the ICC was 0.978 (single rating, \(P<0.001\)) and \(\alpha = 0.996\); for Unit B + the expert the ICC was 0.978 (single rating, \(P<0.001\)) and \(\alpha = 0.996\).

Reliability of data on walking speed, cadence, and stride length was confirmed in the following six datasets: the student data set, the student dataset with no maximum and minimum values, and the expert dataset (for those associated with the stopwatch method); and the automatic calculation dataset and the two manual calculation datasets for the right-foot and left-foot gait cycles (for those associated with the 3D method).

(1) For walking speed, ICC was 0.966 (single rating, \(P<0.001\)) and \(\alpha = 0.994\).
(2) For cadence, ICC was 0.899 (single rating, \(P<0.001\)) and \(\alpha = 0.981\).
(3) For stride length, ICC was 0.943 (single rating, \(P<0.001\)) and \(\alpha = 0.990\).

Examination of the reliability of the two measuring methods revealed high correlations, as described above (Tables 2, 3, and 4).

We then used one-way analysis of variance (ANOVA) and a multiple comparison test (Tukey’s HDS test) to investigate how the difference in measuring methods affected the difference in measured values. The following results were obtained (Table 5).

For walking speed, a significant difference was found among the six datasets (degree of freedom: 5, \(F = 4.270, P = 0.01\)). In a subgroup of \(\alpha = 0.05\) by Tukey’s HDS, the three stopwatch method datasets and the right-foot gait cycle dataset were selected as the first group (\(P = 0.109\)) and five of the datasets (excluding the expert dataset) were selected as the second group (\(P = 0.050\)).

For cadence, a significant difference was found among the six datasets (degree of freedom: 5, \(F = 62.641, P<0.001\)). In a subgroup of \(\alpha = 0.05\) by Tukey’s HDS the three 3D method datasets and the right-foot gait cycle dataset were selected as the first group (\(P = 0.813\)) and the three stopwatch method datasets were selected as the second group (\(P = 0.983\)).

For stride length, a significant difference was found among the six datasets (degree of freedom: 5, \(F = 91.169, P<0.001\)). In a subgroup of \(\alpha = 0.05\) by Tukey’s HDS, the three stopwatch method datasets were selected as the first group (\(P = 1.000\)) and the three 3D method datasets were selected as the second group (\(P = 1.000\)).
DISCUSSION

A clinical evaluation index requires many attributes other than reliability and validity. Shiomi listed some features of the requirements a clinical evaluation index should satisfy in consideration of scaling\(^1\). He also pointed out that, apart from any consideration of these requirements, clinical evaluation indices are requisite in the process of clinical thinking from a therapy-oriented viewpoint.

The method of measuring the 10 m walking time using the stopwatch was checked against the above requirements, and the following conclusions were made.

Safety: this method guarantees safety because the measurer can measure items while keeping an eye on the patient and caring for them if they need help.

High ‘effort efficiency’: this method is highly effort-effective in that it takes less time for measuring and has a lower technical and economic burden (measuring needs only a stopwatch and paper for recording). In some diseases, this method makes it possible to anticipate patients’ activity levels after they leave hospital and to gather a minimum amount of information. Additionally, it is advantageous in terms of knowledge of the results of therapy/training.

High practicability: this method enables
measurement within a short period of time if the walking track is already prepared, as well as the acquisition of variables by a simple conversion, the generation of a report by a PC, and daily measurement if necessary.

Capability of being expressed by a scale: in the stopwatch method, the time required and the number of steps are determined and used to express walking speed, cadence, and stride length as absolute scales by associating these variables with a distance previously measured.

Standardization: the procedures and standards of measurement have been clarified previously, and quite a few reference values by age and sex are available.

High reliability: because of variations in the subjects measured the method is not guaranteed to reproduce measurement results. However, reliability among measurers was (and is still being) investigated in this study, and high reliability is expected.

High validity: high validity was confirmed in relation to external criteria using a parallel method, but has not yet been conclusively identified.

High sensitivity: one report confirmed the therapeutic effect for hemiplegic patients under the condition of the moment of maximum effort (maximum walking speed). A learning curve can be obtained by conducting daily, or even once-a-week measurements. However, inactive conditions in subjects can improve rapidly, and the actual values may be different from the values expected from the learning curve.

High specificity: the stopwatch method purely reflects the functions of walking, since this motion is not complex but instead successive, consisting of continuous unit motion. In the case of experiments that involve complex motion, the stopwatch method is effective in that it does not use variables intertwining in space and time, such as standing, body axis rotation, and acceleration (deceleration). However, consistency and steadiness cannot be ensured.

Appropriateness: in terms of the selection of appropriate items as objects, because a relationship is established between cadence and stride length at the moment of maximum effort, these variables are found to have conformity as variables for the improvement of gait function. Although there was some doubt as to whether they would have conformity at a free walking speed (because cadence and step distance are arbitrary at free walking), high correlation and conformity were observed between gait at maximum walking speed and gait at free walking speed on level ground. As mentioned above, selected items are associated with the activity levels of stroke patients after discharge from hospital (i.e. their social participation), and in the process of clinical thinking or therapy these are core variables in terms of ability to move.

Table 5. Results of walking speed, walking rate, stride length

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<thead>
<tr>
<th></th>
<th>SW Method</th>
<th>3D Method</th>
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<tr>
<td></td>
<td>expert</td>
<td>omit Max &amp; Min</td>
</tr>
<tr>
<td>Walking Speed</td>
<td>Ave. 79.4</td>
<td>80.0</td>
</tr>
<tr>
<td></td>
<td>SD 9.0</td>
<td>8.9</td>
</tr>
<tr>
<td></td>
<td>Max. 98.7</td>
<td>100.6</td>
</tr>
<tr>
<td></td>
<td>Min. 58.4</td>
<td>60.6</td>
</tr>
<tr>
<td>Walking Rate</td>
<td>Ave. 128.7</td>
<td>129.5</td>
</tr>
<tr>
<td></td>
<td>SD 8.6</td>
<td>8.5</td>
</tr>
<tr>
<td></td>
<td>Max. 148.6</td>
<td>147.0</td>
</tr>
<tr>
<td></td>
<td>Min. 106.0</td>
<td>107.6</td>
</tr>
<tr>
<td>Stride Length</td>
<td>Ave. 123.2</td>
<td>123.4</td>
</tr>
<tr>
<td></td>
<td>SD 10.0</td>
<td>9.6</td>
</tr>
<tr>
<td></td>
<td>Max. 153.8</td>
<td>153.8</td>
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<tr>
<td></td>
<td>Min. 105.3</td>
<td>105.3</td>
</tr>
</tbody>
</table>

SW, Stop Watch, 3D, Three-Dimensional Analyzer, Rs, Right side, Ls, Left side.
Reliability

Intra-tester reliability: in this model, it is impossible to prove intra-tester reliability by using a test-retest method, because the measurer measures different things at each measurement. There is a way however to check intra-tester reliability by checking the recorded VTR tapes, but we did not do this, for the following reasons: (1) if we were to set up a screen capable of distinguishing measuring criteria over a 10 m long (or, in fact, 16 m long) track, particularly around the lines where stopwatch measurement starts and ends, at least six cameras would be needed, and all of them would have to be synchronized; (2) in a real-life setting, the measurer judges the start and end in 3D space, but by contrast the judgment on the screen of the VTR is almost two-dimensional. This means that the measurer actively seeks a measurable space for himself/herself, and this behavior is reflected in the data.

Inter-tester reliability: primarily, it is desirable to select experienced therapists as testers, but in this experiment students participated in the measurement. Given this condition rather than simply comparing the data from 5 measurers, we instituted: (1) a comparison using a method to eliminate maximum and minimum values; (2) comparison with data from one experienced measurer, introduced as an external index; (3) a comparison with data from a 3D analyzer (parallel test) as another external index. The results of these comparisons are reported above. In (1), the effect in reducing dispersion was recognized, The ICC (intra-class correlation coefficient) of the students and the expert showed reliability, which would be improved further if the students were to master their measuring skills in some of the areas in which dispersion was found.

Validity

The ceiling effect did not need to be considered in this study. The maximum and minimum measured values were investigated. However, as the difference in the number of steps between all trials was one step, the distribution of the COV varied depending on the mean value.

Content validity: how much did cadence, stride length, and walking speed based on gait cycle parameters reflect the whole gait within the 4 m long measuring range of the 3D motion analyzer, which was set up to cover the middle of the track? This time, very high correlation and high Validity were obtained. For cadence, the contribution ratio was 72.9%; the gradient was around 0.89, and the intercept was 24.1 indicating rather large values. For stride length, the contribution ratio was 85%, the gradient around 0.80, and the intercept 8.9. For walking speed, the contribution ratio was 93%, the gradient 0.84, and the intercept 9.7, showing high correlation and content validity. Criterion related validity and construct validity: was this test actually measuring over a 10 m distance? Was there any difference between intended distance and actual gait distance that was expressed by the position of the feet from the start of measuring to the end of measuring? The purpose of the trial was to measure the number of steps and the time required to walk through a 10 m measuring zone, but how correctly did the values obtained guess cadence and stride length? Further discussion of these questions is needed. The measurement of time taken to walk is reasonable in terms of its implementation in daily activity, but there is some doubt about fitting that measurement to the gait cycle. For example, assume that the position of the heel is marked when the heel contacts the ground over the starting line, and the distance from the starting line (E) is measured. Then the position of the heel is marked again when the heel contacts the ground over the finish line and measuring is suspended, and the distance beyond the finish line (E) is measured. The actual walking distance comes to 10 m (S-E) [absolute value]. To obtain a more accurate value, it would be necessary to deploy people to be in charge of marking, to set up another measuring criterion, or to adopt another measuring method. In a clinical setting the influence of the causes of errors may be reduced, because more steps and a longer time are taken to walk the 10 m.

REFERENCES


