1. Introduction

A typical transtibial (TT) amputee gait pattern has decreased velocity, cadence and stride length compared to age matched controls [1]. When comparing the prosthetic limb with the unaffected side various asymmetries are apparent. Step length, step time and swing time are significantly increased on the prosthetic side while the stance time and single support time are significantly decreased [2]. These variations are also true of transfemoral (TF) amputees with the reduction in velocity, cadence and stride length being even greater [1]. These asymmetries are thought to be due, in part, to the inherent difference in prosthetic lower limb action. This asymmetry does not appear to contribute to increased stress on the contralateral limb but does lead to an increased energy expenditure of ambulation [1] and a higher risk of falls [3].

Gait analysis is usually performed for one of three reasons: (i) to aid the diagnosis of an abnormal gait, (ii) to form the basis for clinical decision making and (iii) to document a patient’s condition [4]. The analysis of an amputee’s gait may be able to influence prosthetic prescription [5] and identify patients with increased mobility risk [6]. It can also assess rehabilitation rate and the effectiveness of different therapies [5].

Observational gait analysis (OGA) is the most commonly used clinical method of analysing the gait of subjects with lower limb prostheses. Despite this, however, the repeatability of OGA in this patient group has been investigated in only a few studies. Saleh and Murdoch [7] compared observational analysis of prosthetic alignment with a marker based measurement system and concluded that visual observation was an “unreliable clinical skill”. Similar conclusions were reached by Ford et al. [8] who also considered the assessment of prosthetic alignment and reported poor agreement between observers, which improved only to moderate agreement when the observers received feedback from the subjects themselves. Menard and Murray [9] used OGA as one tool in an assessment of energy storing prosthetic feet, and although repeatability data are not specifically given, they reported variation in the consistency of observations. The poor performance of OGA in this context led Bach [10] to recommend a strategy for improving the repeatability and validity of OGA which included reducing the number of variables for observation, observing in the coronal plane, and using purpose specific OGA forms.

It is therefore acknowledged that while gait patterns can be observed using video recordings, more complex assessment requires detailed three dimensional motion analysis. However, these complex methods are more accurate but can be time-consuming and are present in very few clinical settings worldwide. The development of a simple and reliable visual gait analysis score could provide a quantitative assessment of amputee gait that is easy to use and accessible to all. It would also provide a way of assessing archived video recordings for retrospective analysis. The Edinburgh Gait Score (EGS) was developed around a similar...
Table 1
Prosthetic observational gait score sheet.

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<tr>
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<tr>
<td></td>
<td></td>
<td>2</td>
<td>1</td>
<td>0</td>
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<tr>
<td><strong>Trunk</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>1 (s)</td>
<td>Arm swing</td>
<td>–</td>
<td>Asymmetric - contralateral &gt; ipsilateral</td>
<td>Normal and symmetric</td>
</tr>
<tr>
<td>2 (s/c)</td>
<td>Vaulting in stance</td>
<td>Visible heel lift on ipsilateral side</td>
<td>Negligible heel lift on contralateral side</td>
<td>Normal</td>
</tr>
<tr>
<td>3 (c)</td>
<td>Lateral trunk lean/side flexion in stance</td>
<td>Marked to swing side</td>
<td>Moderate to swing side</td>
<td>Normal</td>
</tr>
<tr>
<td>4 (s)</td>
<td>Peak sagittal position</td>
<td>–</td>
<td>Moderately backward</td>
<td>Normal</td>
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<tr>
<td><strong>Hip</strong></td>
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<tr>
<td>5 (s)</td>
<td>Peak hip extension in stance</td>
<td>Severe flexn (&gt;15° flexn)</td>
<td>Mod flexn (1–15° flexn)</td>
<td>Normal (0–20° extn)</td>
</tr>
<tr>
<td>6 (s)</td>
<td>Peak hip flexion in swing</td>
<td>Markedly increased (&gt;60° flexn)</td>
<td>Moderately increased (46–60° flexn)</td>
<td>Normal (25–45° flexn)</td>
</tr>
<tr>
<td><strong>Knee</strong></td>
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<tr>
<td>7 (s)</td>
<td>Peak extension in stance</td>
<td>Severe flexion (&gt;25° flexn) or buckling/instability</td>
<td>Moderate flexion (16–25° flexn)</td>
<td>Normal (0–15° flexn)</td>
</tr>
<tr>
<td>8 (s)</td>
<td>Flexion in terminal stance and pre-swing</td>
<td>Markedly late</td>
<td>Moderately late</td>
<td>Normal</td>
</tr>
<tr>
<td>9 (s)</td>
<td>Peak knee flexion/heel rise in swing</td>
<td>Severely increased (&gt;85° knee flexn)</td>
<td>Mod increased (71–85° knee flexn)</td>
<td>Normal (50–70° knee flexn)</td>
</tr>
<tr>
<td>10 (s)</td>
<td>Knee in terminal swing and at initial contact</td>
<td>Severe flexion at initial contact (&gt;25°)</td>
<td>Moderate flexion at initial contact (15–25°)</td>
<td>Normal (5° extn–15° flexn)</td>
</tr>
<tr>
<td><strong>Foot and ankle</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 (s)</td>
<td>Step symmetry</td>
<td>–</td>
<td>–</td>
<td>Normal/symmetric</td>
</tr>
<tr>
<td>12 (s)</td>
<td>1st ankle rocker</td>
<td>Absent</td>
<td>–</td>
<td>Normal</td>
</tr>
<tr>
<td>13 (c)</td>
<td>Foot rotation at initial contact</td>
<td>Absent</td>
<td>Marked internal</td>
<td>Mild internal</td>
</tr>
<tr>
<td>14 (c)</td>
<td>Width of base/lateral thrust</td>
<td>Visible lateral thrust at knee</td>
<td>Decreased width (negligible or scissoring)</td>
<td>Normal (&lt;0.5 pelvic width)</td>
</tr>
<tr>
<td>15 (c)</td>
<td>Circumduction in swing</td>
<td>–</td>
<td>None</td>
<td>Mild</td>
</tr>
<tr>
<td>16 (c)</td>
<td>Swing phase whip</td>
<td>Marked lateral</td>
<td>–</td>
<td>Moderate lateral</td>
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requirement in patients with cerebral palsy and showed good intraobserver and interobserver repeatability with experienced observers [11]. The EGS showed good correlation with other gait scores [12] but was less repeatable with inexperienced users [13]. Similarly, the Rivermead visual gait assessment has been validated in accordance with the recommendations of Bach [10] and to assess whether it could be a repeatable method of evaluating amputee gait.

The aims of this study were to develop a visual gait score in accordance with the recommendations of Bach [10] and to assess whether it could be a repeatable method of evaluating amputee gait.

2. Methods

2.1. Preliminary study

The Prosthetic Observational Gait Score (POGS) was constructed using as a basis the observational gait analysis guidance published in the Atlas of limb prosthetics: surgical, prosthetic and rehabilitation principles [15]. Medical and rehabilitation health professionals were also consulted together with other published sources on the gait of subjects with lower limb prostheses [16–18]. Evidence from the EGS for cerebral palsy was used; however, not all observations were relevant to amputees. A pilot study was then undertaken to assess the feasibility and repeatability of the initial score. This study included five observers and eight patients. As a result of this initial study and further consultations, the original score was modified to address the requirements of the new subject group. The final score was approved by the authors and a kappa score calculated. This resulted in two separate items from the original score, ‘Unequal step length’ and ‘Unequal stance time’, being combined into the single item ‘Step symmetry’; and another item ‘Heel rise in initial swing’ being removed.

2.2. Participants

Sagittal and coronal videos of 10 amputee patients who gave informed, written consent were used in the study. There were six adult female and four adult male unilateral amputees; there were no exclusion criteria relating to cause of amputation, patients age, time since amputation or functional level. Three patients had TT amputations, six had TF amputations and one had a knee disarticulation. Two patients required a walking stick while one required bilateral sticks to aid their walking. Patients had to be able to walk independently for 5 m to permit video recording. Patients were tested whilst wearing their own footwear, at their self-selected walking speed with their lower-limbs adequately exposed. No anatomical markers were used. The duration of the video recordings ranged from 1 min 20 s to 4 min and hence multiple gait cycles in both coronal and sagittal view were collected.

2.3. Gait score

The prosthetic observational gait score was constructed to analyse 16 aspects of amputee gait. The summary score was computed as the sum of the scores for each of the 16 items. The scoring criteria were based on observations made in established practice [15] in clinical prosthetics and it was believed that these would represent the most important pathological features of a TT or TF amputees’ gait pattern that could be seen easily. These observations took into account anatomical levels of trunk, hip, knee, ankle and foot (Table 1). The score included both numerical observations and those based on observer opinion. Each observation could be scored as normal, moderate or severe. Abnormalities on both sides of normal mean were scored in the same way. Scores for numerical items were based on the number of standard deviations (SD) from the mean and these were obtained from the instrumented gait analysis data (Vicon, Oxford, UK) of 13 normal subjects. Observational estimates within 1.5 SD of the mean were considered normal and scored 0, values between 1.5 and 4.5 SD were considered a moderate deviation and scored 1 and values greater than 4.5 SD were considered a severe deviation and scored 2. To aid observers the specified range of movement was noted on the form for each applicable score. For example, peak knee extension in stance of 0–15° flexion was normal and scored 0, while 16–25° of flexion scored 1 and values greater than 25° scored 2. Non-numerical items such as the degree of step symmetry were classified based on observed deviation. Several of these items had fewer possible scoring options. Because the score did not employ opposite ended scores, it was not sensitive to unusual combinations of abnormalities. To mitigate this shortcoming, the score sheet also included a section for observers to record any additional observations, and where such unusual combinations could be noted. This section could also be used to make other comments of clinical significance such as noting any difficulties encountered in scoring the amputees. A set of guidelines was provided to assist in the understanding and measurement of these items (Appendix A). The maximum score for an amputee is 32. Each observation sheet also had a section in which details of the patient, such as amputation side and level and details of prosthetic componentry used could be recorded.

2.4. Data analysis

Six observers who were all familiar with gait analysis scored the patients’ videos using the observational gait score. The observers consisted of one orthopaedic surgeon, two physiotherapists, two prosthetists and one clinical bioengineer. They all had access to video playback facilities that allowed pause and slow motion viewing. There was no time limit set and observers were not directed as to which, or how many, gait cycles should be used for each video analysis. This was done to ensure that the additional variation arising from differing choices by clinicians in clinical practice would also be accounted for in the results. These videos were then re-assessed in a new, randomly selected, order at least 2 weeks after the initial analysis. This allowed for the calculation of intraobserver variation.

2.5. Statistical analysis

The intraobserver and interobserver repeatability for the summary score were assessed with the coefficient of repeatability (CoR) [19]. The CoR reports the range of values in which 95% of the differences between pairs of measurements of the same subject are expected to lie, assuming that the data are normally distributed. This assumption was necessarily an approximation given that the score, and hence differences between repeated observations, are limited to integer values between 0 and 32. Nevertheless, it was believed that the normal distribution could provide an adequate probability model for the variation in the observed values, and this was checked by visual inspection of a histogram of the differences between repeated observations from the study.

Whether agreement is considered good, moderate or poor depends on how changes in the score correspond to clinically significant change. Since each item of the score represents a clinically significant gait abnormality, a CoR of less than 1 would suggest that it could repeatedly detect all clinically significant change in the considered parameters of gait, and would be excellent. Any CoR greater than 1 however represents some insensitivity, and for this study we considered a CoR greater than 1 up to 2 as very good, greater than 2 up to 3 as good, greater than 3 up to 4 as moderate, greater than 4 up to 5 as fair, and greater than 5 was considered poor.

The repeatability of each item of the score was assessed in two ways. Percentage agreement expresses the number of occasions on which two observers agree in their assessment of the same item for the same subject as a percentage of the total number of pairs of observations from different observers for that item. The pooled kappa statistic was also used to take account of the possibility of chance agreement between observers for each item. A kappa of one represents perfect agreement and zero is agreement no different from chance. In our study a score of greater than 0.8 was considered excellent, greater than 0.6 up to 0.8 was considered good, greater than 0.4 up to 0.6 was considered moderate, greater than 0.2 up to 0.4 was considered fair, and 0.2 or less was considered slight. This classification is consistent with medical research practice [20].

3. Results

3.1. Intraobserver repeatability

Each observer made two assessments of the 10 amputee videos. The distribution of differences between observations were plotted on a histogram and confirmed that the assumption of normality for these data was reasonable (Fig. 1). Intraobserver CoR ranged from 1.5 to 4.6 (Table 2) with a mean of 3. Fig. 2 shows the scores from each observer for the two observation sessions for one patient as an example.
3.2. Interobserver repeatability

Three hundred possible pairs of observations were compared for each scored item to give an overall percentage agreement. This amounted to a total of 4800 comparisons. The overall level of agreement ranged from 50% for step symmetry and arm swing to 87% for peak knee extension in stance. Eleven of the 16 items improved in percentage agreement from the first assessment to the second (Table 3). Kappa statistics for the 16 items on the gait score ranged from 0.03 for knee in terminal swing and at initial contact to 0.6 for 1st ankle rocker (Table 3). Out of the 16 items, 4 showed moderate agreement, 7 fair agreement, 4 slight agreement and 1 no agreement. The interobserver CoR was 6 and 5.9 for the first and second assessments, respectively. The score demonstrated poor interobserver repeatability. The ranking of observations based on percentage agreement and kappa are also shown in Table 3.

4. Discussion

The gait score showed good intraobserver repeatability for assessing amputee videos shown by an average CoR of 3. The best observer achieved a CoR of 1.5 representing very good agreement. One observer achieved only fair repeatability between assessments with a CoR of 4.6. Such variation suggests that when this gait score is used by a single observer it can give comparable results, although the degree of consistency is likely to vary with the individual making the observations. Interobserver repeatability was poor with a large variation among the 16 observations. Peak knee extension in stance and 1st ankle rocker were the most reliable items by percentage agreement. They also showed moderate agreement on kappa statistics.

The least repeatable items for percentage agreement were step symmetry and arm swing; however, they showed fair agreement on kappa statistics. The lowest kappa score came from assessment of knee in terminal swing with values showing no more agreement than chance despite an overall percentage agreement of 77%. This is explained by the lack of variation in observations with nearly all observers scoring the patients as normal. A similar lack of variation occurred with the observation of swing phase whip. The lack of sensitivity to abnormality could be explained by the relatively non-pathological gait patterns of our patients. A larger sample of patients with more varied pathology may have aided truer measurement of these observations.

Numerically scored items showed greater repeatability with a mean percentage agreement of 73% compared to 65% for non-numerical. Comparing each anatomical level indicates that the observations at the knee were the most repeatedly measured. This may be because the video footage was always co-planar with the knee since our patients did not exhibit any rotation of the lower limb. Trunk observations were the least repeatable probably because of the difficulty in dissociating movement at the hips, pelvis and trunk. Sagittal video has the benefit of being at a relatively fixed distance from the patient throughout a sequence. Videos of TF amputees showed greater interobserver repeatability with an overall CoR of 5.7 compared to 6.8 for TT. A larger sample would be required to see if this result is significant but it may be that artificial knees are easier to observe.

All observers were very familiar with observational gait analysis although there were differences between them in terms of their training and professional background. The number of observers from any individual profession was not large enough for meaningful statistical analysis of this aspect; however, one trend evident from the data was that some observers consistently...
marked higher or lower for each of the videos and between both assessments. This trend can clearly be seen in Fig. 2 which shows the scores given to a single patient in each of the two observation sessions by each observer. The graph shows that observer 2 consistently gave the patient a low score whereas observers 1 and 5 gave this patient higher scores compared to the other observers. This trend was not narrowed down to the scoring of any specific item and may have arisen from variation between gait cycles in these subjects, and the cycles chosen for analysis by the observers. It is a weakness in the score that it cannot account for this variability, but it is also possible that user judgement can vary despite clear guidance.

This study has highlighted some observations that showed poor repeatability between observers. Peak sagittal trunk position was deemed an important measure and so was included in the score. This observation only showed slight agreement on kappa statistics and may have resulted from clothing obscuring trunk movement. Unexpectedly, arm swing was also one of the least repeatable items. Further evaluation is required to see whether these items could be refined or excluded without compromising the potential clinical usefulness of the score. A larger sample of videos could test the score with a wider range of pathological gait patterns and increase the significance of the findings.

5. Conclusions

This study has shown that the interobserver repeatability of observational gait analysis is, at best, moderate, even when observers follow a structured approach with detailed guidance. Nevertheless, the clinical observation of gait remains the mainstay of prosthetic evaluation, and is essential when instrumented gait analysis is not available. In such instances, this POGS may offer a clinical tool to assist observer evaluation of prosthetic gait and would be most repeatable when used by the same observer to evaluate changes in patients over time.

Appendix A

Prosthetic Observational Gait Score – Explanatory Notes

Indicate on the chart which side, left or right, is being evaluated, and also give details of the side and level of amputation. All items on the chart are referenced to the side under evaluation.

Unilateral and bilateral evaluations

It is expected that most evaluations will be carried out for the prosthetic side only, however it may sometimes be useful to evaluate both sides on two separate charts. When this is done it is not recommended that the left and right score are summed to give an overall score since items 1, 2, 3, 4, 11, and 14 are common to both sides and will therefore contribute twice to the overall score.

Trunk

1. Arm swing

Arms should swing symmetrically with an amplitude appropriate to the walking speed. Score 1 for asymmetric arm swing and use the chart to record whether the ipsilateral or contralateral side is showing the greater swing amplitude. Score 2 for absent or negligible arm swing bilaterally, even when this is due to the use of walking aids. Causes include

- pain or discomfort,
- poor balance/confidence in balance.

2. Vaulting in stance

In normal gait the total vertical displacement of the head and trunk is around 2% of body height, e.g. about 35 mm for a person who is 1.83 m (6 ft.) tall. Vaulting presents as increased vertical motion of the head and trunk effected by plantarflexor activity. Score 2 for marked, e.g. the heel lifts visibly during midstance; score 1 for moderate, e.g. the appearance of heel lift is negligible. Causes of vaulting on the contralateral side include

- prosthesis too long,
- prosthesis functionally too long in swing, e.g. because TF socket too small or pistoning,
- inappropriate swing phase dynamics of prosthetic knee.

3. Lateral trunk lean/side flexion

The subject flexes or tilts the upper body in the coronal plane. This would normally be a tilt to the prosthetic side. Score 1 for moderate, e.g. displacement of the head up to, and in line with, the supporting foot. Score 2 for marked, e.g. displacement beyond the supporting foot. Possible causes include

- short prosthesis,
- insufficient lateral support in socket,
- socket set in abduction,
- pain or discomfort, especially on lateral distal aspect of residual limb,
- weak abductors,
- abducted gait.

4. Peak sagittal position

The trunk should be close to upright throughout the gait cycle. A forward tilt in a TF or higher level amputee may indicate poor knee stability with the amputee contriving to keep the ground reaction force anterior to the knee. Score 1 if the line between hip and shoulder is inclined forward by less than 10°, or reclined backwards. Score 2 if this line is inclined forwards by 10° or more.

Hip

5. Peak hip extension in stance

Judge this from the centre line of the thigh segment, i.e. the centre line of the prosthetic thigh segment for TF patients. Do not try to account for flexion of the residual limb in the socket. Try to judge with respect to the pelvis rather than vertical. Peak extension for the normal hip is between 0° and 20°. Score 1 for flexion between 1° and 15° and for extension of between 21° and 35°. Score 2 for flexion >15° and extension >35°. Causes of decreased peak hip extension include

- anteriorly tilted pelvis/lumbar lordosis,
- hip flexion contracture,
- insufficient initial flexion.

If decreased peak hip extension appears to be due to an anterior tilted pelvis, causes of this include

- insufficient initial flexion in TF socket,
- insufficient support from anterior brim of TF socket,
- weakness of hip extensors or abdominals,
- hip flexion contracture,
- may be a strategy to protect against a potentially unstable knee.

6. Peak hip flexion in swing

As for peak hip extension in stance, judge this from the centre line of the thigh segment and try to judge with respect to the pelvis rather than vertical. Peak flexion for the normal hip is between 25° and 45° flexion. Score 1 for flexion between 10° and 24° and between 46° and 60°. Score 2 for flexion >60° or <10°.

Knee

7. Peak extension in stance (including knee buckling)

The normal knee shows a peak of extension in terminal stance of between 0° and 15° of flexion and is stable with the ground reaction force vector anterior to the knee. Score 1 for flexion
between 16° and 25° (too much) and for extension between 1° and 10° (hyperextension). Score 2 for flexion >25° or extension >10°.
Score 2 for TF patients exhibiting knee instability/buckling of the knee irrespective of peak extension.

Causes of knee buckling in TF subjects include

- prosthetic knee anterior to line of ground reaction force,
- insufficient initial flexion of socket,
- inappropriate dynamic response of foot,
- hip flexion contracture or hip extensor weakness.

8. Flexion in terminal stance and pre-swing (including drop-off)

The normal knee commences a steady rate of flexion at around opposite foot contact and reaches about 30° of flexion by foot-off. For early flexion score 1 when flexion is initiated a little earlier than opposite foot contact, score 2 when flexion is initiated markedly earlier than opposite foot contact while the opposite knee is still extending. For late flexion score 1 when flexion is initiated more than half way through pre-swing, score 2 if initiation of flexion is around foot-off or later. Causes of drop-off include

- dorsi-flexion bumper too soft,
- toe lever too short,
- socket too far anterior in relation to foot.

9. Peak knee flexion/heel rise in swing

The normal knee shows a peak of flexion in initial swing of between 50° and 70°. Score 1 for moderate, e.g. flexion between 71° and 85° (too much) and for flexion between 35° and 49° (too little). Score 2 for marked, e.g. flexion >85° or <35°.

Abnormal knee flexion in TF subjects may also be observed as abnormal heel rise, in which the heel rises posteriorly by an abnormal amount in initial swing. Causes of incorrect heel rise in TF subjects include

- prosthetic knee with wrong amount of friction control,
- poorly adjusted extension aid,
- consequence of a strategy to forcefully flex the hip in initial swing to ensure full knee extension at i.c.

10. Knee in terminal swing and at initial contact

In TF subjects look for terminal swing impact. This is when the prosthetic shank decelerates rapidly when the knee joint reaches maximum extension at the end of swing, i.e. it bangs into the end stop. This may also be audible with some prosthetic knee mechanisms. Score 1 for moderate, for example the impact is visible or audible but not markedly early; score 2 for marked, e.g. the impact is visible and noticeably early, and audible if applicable. Causes include

- insufficient friction control at knee,
- too much tension in extension aid.

In all subjects look at the knee at the instant of initial contact. Score 1 is the knee is flexed between 15° and 25° of flexion, score 2 if it is flexed by more than 25°.

Foot and ankle

11. Step symmetry

Score 1 if there is a moderate difference between sides in either the timing or the length of the steps such that the longer step or swing time is up to 25% longer than on the other side. Score 2 if there is a marked difference in which the longer step or swing time is 25% or more longer than on the other side.

12. 1st ankle rocker

Initial contact should be by the heel followed by a controlled motion of the foot to plantargrade and should be achieved comfortably in advance of opposite foot-off. Too rapid progression to foot flat can sometimes be detected audibly and is known as foot slap. Score 2 on the left for flat foot initial contact or heel contact with over rapid first rocker. Score 2 on the right for prolonged first rocker in which the subject ‘rides on the heel’ so that progression to plantargrade is too slow.

13. Foot rotation at initial contact

The foot rotates, usually externally, during loading response. View in coronal plane and score 1 for moderate rotation and score 2 for marked rotation, such that detail on the side of the shoe is easily seen. Causes include

- inappropriate dynamic response of prosthetic foot, e.g. plantar-flexion bumper too stiff,
- poor control of socket (especially for a new suction socket user).

14. Width of base/lateral thrust

The width between the centres of the heels should be less than 0.5 width of the pelvis. Score 1 if it is estimated to be between 0.5 and 1 times the pelvic width. Score 2 if it is estimated to be greater than the pelvic width. Causes of a wide base include

- prosthesis too long,
- distal segment aligned valgus with respect to proximal,
- pain or discomfort in the crotch area (TF),
- contracted abductors of residual limb (TF),
- poor balance/confidence in balance.

Lateral thrust can be observed at the knee and appears as a sudden motion of the knee into adduction. Score 2 when lateral thrust is marked. Causes of lateral thrust include

- foot positioned too far medially,
- socket set in abduction.

15. Circumduction in swing

The foot follows a curved path in swing. Score 1 if apex of curve results in a distance between heels of 0.5 to 1 times the pelvic width. Score 2 if apex of curve results in a distance between heels of greater than 1 pelvic width. Causes include

- limited range of knee flexion due to mechanical (TF) or physical causes (TT),
- prosthesis too long,
- prosthesis functionally too long in swing, e.g. because TF socket too small or pistoning,
- reluctance to flex knee in TF subjects due to poor confidence.

16. Swing phase whip

The plane of the swinging limb does not lie in parallel to the plane of progression. Results in the foot appearing to flick laterally (lateral whip) or medially (medial whip). Causes include

- knee flexion internally or externally rotated,
- TF socket rotating during gait cycle due to poor fit, or loose, weak musculature,
- internally or externally rotated toe break line.

Conflict of interest statement

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.
References