A review of the foot function index and the foot function index – revised

Elly Budiman-Mak1,2*, Kendon J Conrad3, Jessica Mazza4 and Rodney M Stuck5,6

Abstract

Background: The Foot Function Index (FFI) is a self-report, foot-specific instrument measuring pain and disability and has been widely used to measure foot health for over twenty years. A revised FFI (FFI-R) was developed in response to criticism of the FFI. The purpose of this review was to assess the uses of FFI and FFI-R as were reported in medical and surgical literature and address the suggestions found in the literature to improve the metrics of FFI-R.

Methods: A systematic literature search of PubMed/Medline and Embase databases from October 1991 through December 2010 comprised the main sources of literature. To enrich the bibliography, the search was extended to BioMedLib and Scopus search engines and manual search methods. Search terms included FFI, FFI scores, FFI-R. Requirements included abstracts/full length articles, English-language publications, and articles containing the term "foot complaints/problems." Articles selected were scrutinized; EBM abstracted data from literature and collected into tables designed for this review. EBM analyzed tables, KJC, JM, RMS reviewed and confirmed table contents. KJC and JM reanalyzed the original database of FFI-R to improve metrics.

Results: Seventy-eight articles qualified for this review, abstracts were compiled into 12 tables. FFI and FFI-R were used in studies of foot and ankle disorders in 4700 people worldwide. FFI Full scale or the Subscales and FFI-R were used as outcome measures in various studies; new instruments were developed based on FFI subscales. FFI Full scale was adapted/translated into other cultures. FFI and FFI-R psychometric properties are reported in this review. Reanalysis of FFI-R subscales' confirmed unidimensionality, and the FFI-R questionnaires’ response categories were edited into four responses for ease of use.

Conclusion: This review was limited to articles published in English in the past twenty years. FFI is used extensively worldwide; this instrument pioneered a quantifiable measure of foot health, and thus has shifted the paradigm of outcome measure to subjective, patient-centered, valid, reliable and responsive hard data endpoints. Edited FFI-R into four response categories will enhance its user friendliness for measuring foot health.

Keywords: FFI, FFI-R, FFI adaptation/translation, FFI scores, Foot health measures

Background

Foot problems commonly arise during our daily living activities [1,2]. The prevalence of foot problems in general ranges between 10% and 24% [3]. Their prevalence is higher among older individuals and in chronic rheumatoid arthritis (RA), gout, and diabetes mellitus with peripheral neuropathy [4]. Foot pain and disability can affect workers' productivity, work absenteeism, and other issues [5,6]. Because pain and disability are subjective complaints, they are difficult to quantify without a valid patient report of the degree to which an individual is experiencing foot pain. Without a valid measure, problems arise in documenting foot health status, tracking the progression of diseases, and establishing the efficacy of treatment, including assessment of treatment satisfaction and of health related quality of life from a personal perspective.

In 1991, the Foot Function Index (FFI) was developed as a self-reporting measure that assesses multiple dimensions of foot function on the basis of patient-centered values. The FFI consists of 23 items divided into 3 subscales that...
quantify the impact of foot pathology on pain, disability, and activity limitation in patients with RA [7]. The FFI was developed using the classical test theory (CTT) [8] method. It has been found to have good reliability and validity and has had wide appeal to clinicians and research scientists alike [3,9,10]. In the past 20 years, the FFI has been widely used by clinicians and investigators to measure pain and disability in various foot and ankle disorders and its use has expanded to involve children, adults, and older individuals. Furthermore, the FFI has been widely used in the study of various pathologies and treatments pertaining to foot and ankle problems such as congenital, acute and chronic diseases, injuries, and surgical corrections.

In 2006, the FFI was revised (the FFI-R) on the basis of criticisms from researchers and clinicians; items were added, including a scale to measure psychosocial activities and quality of life related to foot health [11].

A literature review was conducted to develop a theoretical model of foot functioning [12], based on the World Health Organization International Classification of Functioning (ICF) model. The FFI-R items were developed from the original 23 FFI items, and more items were added as a result of the literature review. As a result of clinicians and patients’ input, the final draft of the FFI-R, which consisted of 4 subscales and 68 items, was completed. The results were the FFI-R long form (FFI-R L; 4 subscales and 68 items) and the FFI-R short form (FFI-R S; 34 items) as total foot function assessment instruments. Both the 68-item and 34-item measures demonstrated good psychometric properties.

The FFI-R in its current form is one of the most comprehensive instruments available. However, in a review article [13], questions were raised about the unidimensionality and independence of FFI-R subscales, and we did not include such reports in our previous article about the FFI-R [11]. We carefully reviewed the comments about the FFI-R and assessed the unidimensionality of the subscales by use of the Rasch model. On the basis of these critiques, the FFI-R required a periodic revision of its metrics to ensure it represented patient-centered health values and state-of-the-art methodology.

Our aim is to assess the contribution of the FFI and FFI-R to the measurement of foot health in the fields of rheumatology, podiatry, and orthopedic medicine. This assessment should enable us to reflect on and improve the quality of the measure. Therefore, we conducted a systematic review of literature pertaining to the FFI and FFI-R that has been published in the English language from October 1991 through December 2010. The objectives were to: (i) Assess the prevalence of uses of the FFI and FFI-R in clinical studies of foot and ankle disorders; (ii) Describe the utility and clinimetric properties of the FFI and FFI-R as they have been applied in various clinical and research settings; (iii) Enumerate the strengths and weaknesses of the FFI and FFI-R as reported in the literature; (iv) Address the suggestions found in the literature for improving the FFI-R metrics.

### Methods for systematic search of the literature

This study was about a systematic review of articles in which the FFI and/or FFI-R were used as measures of a variety of foot and ankle problems. Relevant studies were identified by English language publication searches of the electronic bibliographic databases Pub Med/MEDLINE, EMBASE, BioMedLib and Scopus from October 1991 through December 2010.

### Search terms and eligibility criteria

The key words: foot function index, FFI scores, foot function index scores, and foot function index revised (FFI-R). were used as search terms and was applied to all databases. FFI instruments/measure and/or FFI-R instruments/measure had to be mentioned in the abstracts and in the full articles to be collected for in-depth scrutiny. Articles fulfilling the inclusion criteria were selected for the review. The article criteria included: (i) the words foot function index/FFI or revised foot function index/FFI-R in its reports/measures; (ii) full-length articles; (iii) written in English and published from October 1991 through December 2010; (iv) the study population described needed to have foot complaint(s)/problems; and (v) regardless of the country conducting the study, the full-length article

### Table 1 Study type, sample size and sample characteristics

| Study type         | Number | Sample size (N) | N Male | N Female | Age (SD) |
|--------------------|--------|----------------|--------|----------|----------|
| Measurement        | 17     | 1236           | 458    | 763      | 54.9 (6.4) |
| Surgery            | 30     | 1512           | 648    | 857      | 45.1 (15.7) |
| Orthoses           | 19     | 1101           | 493    | 521      | 43.0 (15)   |
| Other intervention | 4      | 170            | 55     | 115      | 47.6 (6.1)  |
| Observational      | 8      | 695            | 260    | 432      | 52.2 (27.9) |
| Total              | 78     | 4714           | 1914*  (41%) | 2688*  (57%) | 48.58 (4.9) |

*Gender not reported in 3 studies: Slattery, M [82] (2001), Clark, H [85] (2010) and Kulig, K [88] (2009).
must have been published in English or in a foreign language with the abstract in English.

**Objectives with method of data collection and organization of tables**

Selected articles that fulfilled the criteria were independently reviewed and collected by the authors to address the objectives and organize collected data into several tables.

**Objective 1. Uses of the FFI and FFI-R**

We created four tables to address the first objective of describing the measurement's uses (Tables 1, 2, 3, and 4).

**Objective 2. Utility and clinimetric properties**

We designed a data-collection form to address the second objective. This form was assessed in a pilot study by collecting data from ten articles out of the collection of qualified articles; it was revised before being used in its current format. The variables used in this data-collection form were: (i) the instrument and year the article was published; (ii) the first author's name; (iii) the objectives of the study; (iv) the population characteristics, sample size, and diagnosis; (v) psychometric analysis (reliability and validity, etc.); (vi) items/domains/subscales of the FFI or FFI-R used in the study; (vii) response type; and, (viii) a short summary evaluation of each study. Therefore, this data form recorded the analytic statements extracted from each article, and 6 tables were created (Tables 5, 6, 7, 8, 9, and 10). Data were arranged in each table in chronological order.

**Objective 3. Enumerate the strengths and weaknesses of the FFI and FFI-R as reported in the literature**

This was a qualitative summary of the results as found in Table 5 and Table 6.

**Objective 4. Improving the FFI-R metrics**

Table 11 summarizes results of the Rasch analysis. This was a reanalysis of the FFI-R database collected in 2002 with the aim of improving FFI-R metrics.

**Descriptive analysis methods**

Quantitative data were reported using simple statistics expressed as the sum, means, and standard deviations for continuous variables and as frequencies for categorical data. (Tables 1, 2, 3, and 4) Analytic statements and evaluations/comments for each article collected are summarized in Table 12. This depicts the summary of

| Table 2 FFI uses across studies in foot and ankle disorders including diagnoses |
|---------------------------------|-------|-------|-------|-------|-------|
| Diagnosis                        | Measure | Surgery | Orthosis | Observational | Other | Total |
| Rheumatoid arthritis             | 6      | 5      | 7       | 3               |       | 21    |
| Osteoarthritis                   | 2      | 1      |        | 1               |       | 4     |
| Juvenile arthritis               |        |        | 1       |                 |       | 1     |
| Hallux valgus                    | 2      | 2      | 1       |                 |       | 5     |
| Hallux rigidus                   |        |        | 3       |                 |       | 3     |
| Plantar fasciitis/heel pain      | 2      | 2      | 4       | 3               | 11    | 11    |
| Metatarso phalangeal arthritis   | 2      | 2      |         |                 |       | 4     |
| Chronic foot pain                | 3      | 2      |         |                 |       | 6     |
| Foot and ankle fracture          | 1      | 5      | 1**     | 1               |       | 8     |
| Posterior tibial tendon pain     |        |        |         | 1               |       | 2     |
| Bone graft                       | 1      |        |         |                 |       | 1     |
| Ankle deformity                  | 2      |        |         |                 |       | 2     |
| Flat foot                        | 1      |        |         |                 |       | 1     |
| Cavovarus Charcot-Marie-Tooth    | 2      |        |         |                 |       | 2     |
| Osteo-chondral lesion of talus-tibia | 1 |        |         |                 |       | 1     |
| Failed total ankle arthrodesisis | 1      |        |         |                 |       | 1     |
| Club foot                        | 1      |        |         |                 |       | 1     |
| Diabetic neuropathy              | 1      |        |         |                 |       | 1     |
| Mid foot pain                    | 1      | 2      |         |                 |       | 3     |
| Paget disease                    |        |        | 1       |                 |       | 1     |
| Total                            | 17     | 31*    | 19      | 8               | 4     | 79*   |

*Two different diagnoses occurred in one study, **Hemophilic ankle arthropathy.
FFI and FFI-R uses as illustrated in Objective 2, and in six tables (Tables 5, 6, 7, 8, 9 and 10).

**Rasch analysis method**

To address specific critiques of the FFI-R found in the literature, the unidimensionality of the FFI-R and its subscales were evaluated against the Rasch model. The statistical package Winsteps version 3.72.3 [14] was used to conduct a principal components analysis (PCA) of the standardized residuals to determine whether substantial subdimensions existed within the items [15-17] and whether the FFI-R L, the FFI-R S, and the 5 subscales were unidimensional. The criterion used to define unidimensionality was a large variance (> 40%) explained by the measurement dimension [18]. Unexplained variance in the first contrast of the data should be small and fall under the criterion of 15% for a rival factor. We chose a ratio of variance of at least 3 to 1 in the first principal component [19], compared to the variance of the first component of residuals.

**Rasch reliability statistics**

Reliability was estimated with Cronbach’s Alpha and Rasch person reliability statistics. Both indices reflect the proportion of variance of the person scores or measures to total variance (i.e., including measurement error). Unlike Cronbach’s Alpha, Rasch person reliability is based on the estimated locations of persons along the measurement continuum, excluding those with measures reflecting extreme (zero or perfect) scores and including cases with missing data. For both indices, our criterion for acceptability was .80.

**Table 3 FFI Uses across studies conducted internationally**

| Country        | Measure | Surgery | Orthosis | Observational | Other | Total |
|----------------|---------|---------|----------|---------------|-------|-------|
| Australia      | 2       | 1       | 1        | 4             |       |       |
| Austria        | 2       |         |          | 2             |       |       |
| Brazil         |         | 2       |          | 2             |       |       |
| Canada         | 2       |         | 1        | 3             |       |       |
| Czech Rep.     | 2       |         |          | 2             |       |       |
| France         | 1       |         |          | 1             |       |       |
| Germany        | 1       | 1       | 2        | 1             | 5     |       |
| Japan          | 1       |         |          | 1             |       |       |
| So. Korea      |         |         | 1        | 1             |       |       |
| Netherlands    | 2       | 7       |          | 9             |       |       |
| New Zealand    | 1       |         |          | 1             |       |       |
| Slovenia       | 1       | 1       | 1        | 2             |       |       |
| Sweden         | 1       |         |          | 1             |       |       |
| Taiwan         | 1       |         |          | 1             |       |       |
| Turkey         | 1       |         |          | 2             | 3     |       |
| UK             | 2       | 1       | 3        | 2             | 8     |       |
| USA            | 8       | 12      | 9        | 3             | 8     | 32    |
| **Total**      | 17      | 31      | 18       | 8             | 4     | **78** |

**Table 4 FFI Full scale and subscale used across studies**

| FFI             | Measure | Surgery | Orthosis | Observational | Other | Total |
|-----------------|---------|---------|----------|---------------|-------|-------|
| FFI Full scale (3 domains) | 10      | 21      | 14       | 6             |       | 51    |
| FFI Pain scale  | 2       | 1       | 2        | 2             | 3     | 10    |
| FFI Disability scale | 1       |         |          |               |       | 1     |
| FFI Pain and Disability scale | 3       | 3       | 1        | 1             | 8     |       |
| FFI - 5pts      | 1       | 4       |          |               |       | 5     |
| FFI-R Long form | 1       |         | 2        |               | 3     |       |
| FFI Used in studies | 17      | 30      | 19       | 8             | 4     | 78    |
| Instrument | 1st Author | Objective | Population (N, Sex, Age, Dx, location) | Psychometric analysis | Items/domains/subscales/item sources | Response type | Summary evaluation |
|------------|------------|-----------|---------------------------------|---------------------|--------------------------------------|--------------|-------------------|
| Foot Function Index, 1991 | Budiman-Mak, E [7] | Instrument Development | N: 87 (78 male) | Classical Test Theory | 23 items | Visual Analog Scale | Good clinimetrics, applicable to various age groups and varieties of foot and ankle pathologies. Conclusion: Positive |
| Foot Function Index Pain (left/right), 1996 | Saag, KG [23] | Foot Function Index pain scale; Compare right/left foot | N: 63 (13 male) | Classical Test Theory | 9 items | Visual Analog Scale | This measure of right vs. left side of the foot showed good clinimetric properties Conclusion: Positive. |
| Foot Function Index/ Foot Health Status Questionnaires (FHSQ), 1998 | Bennet PJ [9] | Development of FHSQ, a new measure | N: 111 (25 male) | Classical Test Theory | 13 items | Likert | FHSQ has good clinimetrics. Conclusion: Positive. |
| Foot Function Index/ Ankle Osteoarthritis Score (AOS), 1998 | Domsic, RT [24] | AOS consisted of Foot Function Index pain and disability scales | N: 36 (12 male) | Classical Test Theory | 18 items | Visual Analog Scale | AOS had good clinimetrics. Conclusion: Positive. |
| Foot Function Index/ Foot Function Index-5pts in Dutch, 2002 | Kuyvenhoven, MM [3] | Foot Function Index in Dutch | N: 206 (78 male) | Classical Test Theory | 15 items | 5-point Likert | Adaptation of Foot Function Index to 5 point Likert, used as a generic measure in foot and ankle problems. Conclusion: Positive. |
| Foot Function Index/ Foot Health Status Questionnaire (FHSQ), 2002 | Landorf, KB [10] | Validation of FHSQ to Foot Function Index | N: 17 (4 male) | Non-parametric statistics | FHSQ | S-point Likert | FHSQ has less items than FFI and was printed in larger font for ease of use. |
Table 5: Studies of foot function measures (Continued)

| Study | Mean age (SD) | Comment |
|-------|---------------|---------|
| Foot Function Index/ Foot Impact Scale (FIS), 2005 | 44.6 (10.5) (Range 24–72) | 13 items, Conclusion: Positive. |
| Helliwell, P [29] | Location: Australia | Validate with Health Assessment Questionnaire (HAQ), FFI, and Manchester Foot Disability Questionnaires (MFDQ) |
| | Dx: Painful plantar fasciitis | Item Response Theory, FIS Visual Analog Scale |
| Foot Function Index, 2005 | 61.7 (Range 28–89) | 51 items, Conclusion: Positive. |
| Agel, J [25] | Location: UK | Patient Foot Function Index |
| | N: 148 (34 male) | Correlation statistics |
| | Mean age: 61.7 (Range 28–89) | Dx: RA Foot Pain |
| | Dx: RA Foot Pain | 2 domains |
| | Location: UK | Patient Foot Function Index |
| | N: 54 (22 male, 6 unknown) | Correlation statistics |
| | Mean age: 52.8 (SD=12.3) (Range 19–74) | 23 items, Conclusion: Positive. |
| | Dx: Non-traumatic foot/ankle complaints | |
| Foot Function Index, 2005 | 55.4 (SD=11.4 years); Dx: RA 12.7 years (SD=10.4) | 23 items, Conclusion: Positive. |
| Shrader, JA [28] | Location: USA | Plantar foot pain |
| | N: 20 (0 male) | |
| | Mean age: 55.4 (SD=11.4 years); Dx: RA 12.7 years (SD=10.4) | Index 23 items |
| | Dx: Navicular joint dropped and foot pain | Foot Function Index |
| | Location: USA | Visual Analog Scale |
| Foot Function Index-R with Foot Function Index, 2006 | 69 (range: 38–88) | 68 items (long), Conclusion: Positive. |
| Budiman-Mak, E [11] | Location: USA | Navicular joint dropped and foot pain |
| | N: 97 (90 male) | Foot Function Index |
| | Mean age: 69 (range: 38–88) | Likert scale (replaced Visual Analog Scale) |
| | Dx: Chronic foot and ankle complaints | Foot Function Index-R had 3 domains, plus 4th psychosocial domain added to assess quality of life. |

Note: FIS items were derived from RA patients (consisted of impairment/shoes and activities/participation subscales), with good clinimetric properties.
### Table 5 Studies of foot function measures (Continued)

| Study Description                                                                 | N, Gender       | Correlation Statistics | Clinicians and patients                                                                 | Location          | Notes                                                                 |
|------------------------------------------------------------------------------------|-----------------|------------------------|----------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------------------|
| Comparing Foot Function Index with Health Assessment Questionnaires (HAQ) & SFC  | N: 78 (11 male) | Correlation statistics | Strong correlations of HAQ and Foot Function Index scores, HR and CV also reflected in Foot Function Index scores and were highly correlated with Rand 36 items Short Form Health Survey (SF36). | Turkey            | Mean age: 50.65 (SD=10.7); RA duration 13.96 (SD=8.09) Conclusion: Positive |
| Validity test in foot health and general physical health                            | N:69 (25 male)  | Correlation statistics | The 3 domains of Foot Function Index demonstrated moderate-high correlation with SF36, thus it was reasonable to use Foot Function Index to monitor outcomes. | USA               | Mean Age: 46 (Range 16–82) Conclusion: Positive.                     |
| Reliability and validity of test, compared with Foot Function Index                | N:11 (1 male)   | Correlation statistics | Only AOFAS hallux for pain correlated with Foot Function Index pain scale.               | USA               | Mean age: 54 (Range: 40–72) Dx: RA without foot complaints Conclusion: Positive. |
| Measure forefoot damage                                                             | N:62 (15 male)  | Correlation statistics | Foot Function Index function subscale correlated with WOMAC and DAS-44. Foot Function Index pain score correlated with forefoot pain. Foot Function Index function score correlated with hind foot problem. Conclusion: Positive. | USA               | Mean age: 55.7 (SD=13.11) Dx: RA forefoot complaints, duration of 96 months |
| Location: Netherlands | Location: UK | N:45 (11 male) | Correlation Statistics | Validity of AOFAS scale | Numeric rating scale | Mean age: 55 years (range=15-81) | Dx: Hallux deformities |
|----------------------|--------------|----------------|------------------------|------------------------|---------------------|-----------------------------|---------------------|
| Ibrahim, T [33] Testing the criterion validity of clinical rating components of AOFAS with Foot Function Index | WU, SH [36] Reliability and validity measure of PCS of SF-26, Taiwan version; | N:50 (planta fascitis); mean age 46.9 (SD=10.6) | Cross-cultural adaptation | Foot Function Index | Visual Analog Scale | Foot Function Index Taiwan Chinese consisted of 21 items. Could measure non-traumatic and traumatic foot and ankle problems. The floor score was 10%, in sample with fractures. | Conclusion: Positive. |
| Dx: Hallux deformities | Location: UK | N:29 (ankle/foot fracture); mean age 37.2 (SD=14.8) 25 male | 21 items | 3 domains | The order of items was changed. Clinician and patient | |
| Location: Taiwan | | | | | | |
| Location: Germany | | N:53 (14 male) | Cross-cultural adaptation | Foot Function Index-D | Numeric rating scale | Foot Function Index underwent German translation. Foot Function Index-D added 3 new items and revised 8 items of the Foot Function Index and had demonstrated good clinimetrics. | Conclusion: Positive. |
| Naal, FD [34] Foot Function Index-D, | | | | | | |
| Age: 57.2 (SD=13.7) Range (18-77) | Index-D 18 items (pain & disability subscales) | 2 domains | 2 domains | Clinician and patient | |
| Dx: Foot complaints | Location: Germany | | | | | |
| Instrument; author year | Reliability e.g., IRT, CTT ICC, kappa, test-retest | Cronbach’s alpha | Instrument /Domain N items/ Item generated sources | Validity (Face, content, criterion or construct) and other measures | Response to change | Completion time | Sample N diagnoses conclusion |
|-------------------------|---------------------------------------------------|-----------------|-------------------------------------------------|-------------------------------------------------|------------------|-----------------|-----------------------------|
| FFI; Budiman Mak, E [7] 1991 | CTT Total: 0.96 FFI ICC total: 0.87 | 0.70 | Pain: 0.70 | 23 items | Face: yes | Yes | 10 minutes | N=87 Early rheumatoid arthritis |
| FFI pain subscale (R/L foot); Saag, KG [23] 1996 | CTT ICC: 0.79-0.89 | 0.94-0.96 | FFI side-to-side; Clinician and patient | Face: Yes | Content: Yes | | | |
| FFI and AOS; Domsic, RT [24]1998 | CTT ICC: 0.97 | 0.95 | Pain: 0.95 | 18 items; Clinician | Construct: Yes | | | |
| FFI & FHSQ; Bennet, PJ [9] 1998 | CTT ICC | 0.85-0.88 | FHSQ | Criterion: Yes | | 3-5 minutes | N=255 Dx: Hallux valgus osteoarthritis |
| FFI (5 pt); Kuyvenhoven, MM [3] 2002 | CTT ICC: 0.64-0.79 | 0.88-0.94 | FFI (5 pt) Total: 0.93 | 15 items | Concurrent validity: Yes | Yes | | |
| FFI & FIS; Helliwell,P [29] 2005 | IRT Not performed | | FIS ICC | 51 items | Face: Yes | Content: Yes | | |
| | | | Impairment/shoes: 0.84 Activities/participation: 0.84 | 2 subscales | Construct: Yes | | | |
| | | | clinician and patient | Goodness of Fit | | | |
Table 6 Clinimetric properties of patient-reported foot function measures (Continued)

| Study | Foot Function Measure | ICC | Reliability | Conclusion |
|-------|-----------------------|-----|-------------|------------|
| FFI; Agel, J [25] 2005 | FFI | Total: 0.68 | 19 items from pain and difficulty subscales were deleted | FFI was good for individuals with low level functioning. |
| | All subscale values were significant at .01 level | | | |
| FFI-R; Budiman-Mak, E [11] 2006 | IRT | Total: 0.95 | FFI-R | 15 minutes N=92 | |
| | Person reliability: 0.96 | Pain: 0.93 | Criterion: Yes | 15 minutes N=92 | |
| | Long form (68 items); Short form (34 items) | Duration: 15 minutes | FFI-R | Pain: 0.93 | |
| | Clinician and patient | Minimal floor effect (4.5%) | Conclusion: Positive | |
| | Activity limitation: 0.88 | Goodness of Fit | | |
| | Psychosocial: 0.86 | | | |
| FFI & SF 36; SooHoo, NF [27] 2006 | Pearson Correlation of FFI to SF-36 | Activity limitation: -0.23 to -0.61 | Moderate correlation between FFI and SF-36 | N=69 |
| | Pain: -0.10 to -0.61; Disability: -0.23 to -0.69 | 23 items | | |
| | Activity limitation: -0.23 to -0.61 | 3 domains | | |
| FFI AOFAS; Baumhaur, JF [32] 2006 | ICC AOFAS Summary Scores: Hallux 0.95 Lesser toes: 0.8 Pearson's correlations mean value AOFAS Hallux vs. FFI: r=0.80, AOFAS lesser toes vs FFI: r=0.69, Pain subscale AOFAS Hallux vs. FFI summary score: r=0.31 | FFI | Content: Yes | Rheumatoid Hallux and lesser toes |
| | 23 items | Criterion: Yes | N=11 | |
| | 3 domains | Ceiling effect noted in lesser toe activity subscale | Conclusion: Positive | |
| FFI FHSQ; Landorf, KB [101] 2007 | ICC measures were reported; Minimal important difference (MID) was the focus of this clinical measure | MID | | N=175 |
| | FHSQ: Pain 14, Function 7, General health 9 | | Plantar fasciitis | |
| Study | Measure/Version | Methodology | Reliability | Validity | Conclusion |
|-------|-----------------|-------------|-------------|----------|------------|
| FFI, AOFAS; Ibrahim, T [33] 2007 | Test-retest AOFAS; pre and post operation was no different; 41% response rate. Pearson correlation with FFI was −0.68 for all the subjective components of AOFAS. Hallux module subjective component was −0.46 | ICC CA | Criterion: yes | Yes | N=45 Foot and ankle problems |
| FFI, FFI Taiwan Chinese; Wu, SH [36] 2008 | | | | | |
| FFI, FFI-German Naal FD [34] 2008 | | | | | |
| Budiman-Mak et al. Journal of Foot and Ankle Research 2013, 6:5 Page 11 of 37 | http://www.jfootankleres.com/content/6/1/5 |
Response category analysis

One requirement of the Rasch model is monotonicity: the requirement that, as person ability increases, the item step response function increases monotonically [20]. This means that choosing one categorical response over the prior—for example, moving from selecting “2 = A little of the time,” to selecting, “3 = Most of the time,”—increases with person ability. The proper functioning of the rating scale is examined using fit statistics, where: (i) outfit mean squares should be less than 2.0, (ii) average measures advance monotonically with each category, and (iii) step calibrations increase monotonically [21,22].

Results

Review of the literature

Articles were obtained by using the search method defined in the Methods section; the search results included 752 articles from PubMed/MEDLINE and 640 articles from Embase. Further screening and selection procedures, as detailed in Figure 1, yielded 182 full-text articles. Of these, 53 articles were qualified for review. Twenty-five more articles were obtained from the search engine BioMedLib and from manual searches. A total of 78 articles qualified for this review, summarized and categorized into several tables.

Table 6 Clinimetric properties of patient-reported foot function measures (Continued)

| Measure | Property | Scale | Protocol | Conclusion |
|---------|----------|-------|----------|------------|
| FFI-R, Rao S [75] 2009 | This report is about minimal detectible change (MDC90) a measure of clinical importance. | FFI-R long 68 items | MDC Total 5 Pain 5 | N=22 Orthoses treatment in mid foot arthritis |
| FFI-R, Rao S [76] 2010 | A measure of clinical importance of orthoses intervention | FFI-R long 68 items | MDC Total 5, Pain 5, Stiffness 6, Disability 7, Activity limitation 7, Psychosocial 7. | Effect Size (ES) Total 0.4, Pain 0.6, Activity limitation 0.4, MDC and ES findings are significant. |

Objective 1: Assessment of the prevalence of the FFI or FFI-R usage, population characteristics, and study locations

Among the 78 studies, we identified 4714 study participants for whom the FFI or FFI-R instrument had been used to measure foot health. This sample consisted of 1914 (41%) male participants and 2688 (57%) female participants, with a mean age of 48.58 years (SD, 4.9 years). There was a discrepancy of 2% between the sums of male and female participants, because gender was not reported in three studies (Table 1). Most of the participants were individuals and young adults, and a few studies involved juvenile participants. The types of studies included measurement practice studies (n=17), surgery studies (n=30), studies of orthotics (n=19) or other clinical interventions (n=4), and observational studies (n=8). We identified 20 different diagnoses of foot and ankle pathology that were measured by FFI and FFI-R (Table 2). Among them, RA and plantar fasciitis were the two most common diagnoses and were also noted to be the most painful and disabling foot conditions. These studies were conducted by investigators in 17 countries; the United States, the Netherlands, and the United Kingdom were the three most frequent users of the FFI and FFI-R in studies involving foot and ankle problems (Table 3).
| Instrument 1st Author | Objective | Population (N, Sex, Age, Dx, location) | Analysis | Items/ Domains/ Subscales | Response type | Summary evaluation |
|----------------------|-----------|----------------------------------------|----------|---------------------------|---------------|-------------------|
| Foot Function Index (FFI), 2000 Lin, S [39] | Validation of AOFAS forefoot outcomes of arthrodesis surgery | N: 16 Mean age: 44 (SD=13.96) 8 male | Pre-post surgery | FFI VAS | Both FFI and AOFAS scores were improved at post surgery. |
| | | Dx: Tarsometatarsal injury/ degenerative arthritis | | | |
| | | Location: USA | | | |
| FFI, 2002 Watson, TS [61] | Validation with VAS pain scale with SF-36 short form in plantar fasciotomy | Group I N (control): 75 Mean age: 46 (range: 20–78) 14 male | Retrospective observational Follow up duration 26.4 months | FFI VAS | FFI scores were improved. |
| | | Group II N (surgery): 46 Mean age: 46 (Range: 25–78) 9 male | | | |
| | | Dx: Sub-Calcaneal pain syndrome | Validation with VAS pain scale SF-36 short form | 23 items | FFI scores reflected activities of daily living. SF-36 scores reflected satisfaction of physical and role model. |
| | | Location: USA | | | |
| FFI, 2003 Mulcahy, D [56] | Surgery- Reconstruction of the forefoot; FFI scores were used to test if there was correlation with WOMAC, AOFAS HMIP, and AOFAS LMIP. | N: 79 14 male Mean age: 59 (Range: 24–80) | Retrospective observational; Follow up 6yrs.+3 mo (6mo-19 years) | FFI; 23 items; 3 domains VAS | FFI pain subscale was used to monitor pain in both groups. |
| | | Dx: RA forefoot deformity | | | |
| | | Mean age of surgery: 52 years (range: 23–79) | | | |
| | | Group 1 stable 1st ray (no surgery) | | | |
| | | Group 2: 1st ray surgery | | | |
| | | Location: Canada | | | |
| FFI, 2004 Ibrahim T [48] | Surgery- MTP joint replacement; Validation of AOFAS Hallux scale scores with FFI scores from those who did not have surgery and those who had surgery | N: 8, 1 male | Retrospective observational; Follow up for 17 months | FFI VAS | Correlation observed between the scores of AOFAS and FFI |
| | | | | | |
| | | Mean age: 58 (Range: 51–80) | | 23 items | Note: AOFAS Hallux scale had not been validated. |
| | | Dx: Hallux rigidus | | | |
| | | Location: UK | | | |
| | | | | | |

Table 7 Studies using foot function measures in surgical interventions
| Year | Authors | Study Design | Surgery | Description | Study Population | Data Collection | Analysis | Outcome |
|------|---------|--------------|---------|-------------|------------------|----------------|----------|---------|
| 2004 | Vallier, HA [52] | Retrospective observational | Surgery-Open reduction internal fixation; Correlation of FFI and musculoskeletal function assessment (MFA) | N: 100 60 male | Follow up 36 months (12–74 months) | 23 items | Conclusion: useful |
|      |         |              |         |             | Mean age: 32.6 (Range: 13–77) |              |          |         |
|      |         |              |         |             | Dx: Talar neck fracture |              |          |         |
|      |         |              |         |             | Location: USA |              |          |         |
| 2005 | Taranow, WS [49] | Retrospective observational case review | Surgery- metallic hemiarthroplasty: Do FFI scores improve at post-operation | N: 28 17 male | Follow 33.4 months (3–mo-111mo) | 23 items | Conclusion: useful |
|      |         |              |         |             | Mean age: 52.9 (Range: 38–71) |              |          |         |
|      |         |              |         |             | Dx: Hallux rigidus |              |          |         |
|      |         |              |         |             | Location: USA |              |          |         |
| 2005 | Grondal, L [40] | RCT not-blinded, ANOVA and multiple comparisons | Surgery-Athrodesis vs. Mayo resection of MTP; FFI scores as outcomes | N: 31; 26 male | FFI VAS | 23 items | Conclusion: useful |
|      |         |              |         |             | Mean age: 54 yrs (Range: 33–77) |              |          |         |
|      |         |              |         |             | Resection N= 16 |              |          |         |
|      |         |              |         |             | Fusion N= 15 |              |          |         |
|      |         |              |         |             | Dx: RA painful forefoot deformity |          |          |         |
|      |         |              |         |             | Location: USA |              |          |         |
| 2005 | Daniels, TR [62] | Observational | Surgery -Free tibular graft; FFI scores were validated with MODEMS and SF-36 short form | N: 28, 13 male | FFI 21 items (2 items about orthoses were not applicable) | Likert | The scores of FFI, SF-36 and MODEMS were demonstrating similar improved outcomes at post-surgery |
|      |         |              |         |             | Mean age: 52 (Range: 22–76) |              |          |         |
|      |         |              |         |             | Dx: Vascularized fibular bone graft |              |          |         |
|      |         |              |         |             | Location: Canada |              |          |         |
| 2005 | Lee, S [63] | Retrospective observational | Surgery -Isolated sesamoidectomy; FFI disability sub-scale validated with | N: 32; 8 male | FFI 9 items | VAS | The scores of FFI disability and VAS pain sub-scales were correlated. |
|      |         |              |         |             | Mean age: |              |          |         |
|      |         |              |         |             | Dx: |              |          |         |
|      |         |              |         |             | Location: |              |          |         |
| Study | Year | Authors | Type of Surgery | Instruments | Pain Subscale | Outcome |
|-------|------|---------|----------------|-------------|--------------|---------|
| FFI, 2006 SooHoo, NF [64] | Surgery: Any type of foot and ankle surgery; Validating AOFAS, SF-36 and measuring Standard Response Mean (SRM) and effect size (ES) | VAS pain scale and SF-36 short form | Mean age: 37.2 (Range: 18-65) | 62 month | 1 domain: disability scale | Of the instruments used, scores of the pain subscale was the only measure reflecting high SRM (−0.83) and ES (−0.86). Therefore, pain is the most important outcome in studies regarding chronic foot and ankle pain. |
| FFI, 2006 Van der Krans, A [41] | Surgery: Calcaneal Cuboid arthrodesis; Correlation with AOFAS clinical rating index (CRI) of the hind foot | | Mean age: 40 (Range: 21–69) | | | Conclusion: useful |
| FFI, 2006 Harris, M [53] | Surgery: High impact fracture repair; Correlation with Musculoskeletal function assessment (MFA) | | Mean age: 45 (Range: 17–81) | | | Conclusion: useful |
| FFI, 2006 Stegman M [42] | Surgery: Triple arthrodesis; Correlation with AOFAS hind foot scores | | Mean age: 40.5 (Range: 14–79) | | | Conclusion: useful |
| Study | Authors | Year | Type of Procedure | Domain(s) | Number | Gender | Follow-up | Measure(s) | Results |
|-------|---------|------|-------------------|-----------|--------|--------|----------|------------|---------|
| FFI, 2007 | Jung, HG | 2007 | Fusion of tarsometatarsal joint | 2 domains | 67; 12 M | Retrospective | FFI, VAS | Scores of the FFI, SF-36 AOFAS and VAS pain scale were markedly improved at post-surgery |
| FFI, 2008 | Vesely, R | 2008 | TibioCalcaneal arthrodesis; Correlation with ankle-hind foot score | 3 domains | 20; 16 M | Retrospective | FFI, VAS | The scores of FFI and ankle hind foot were improved. |
| FFI, 2008 | Stropek, S | 2008 | Arthroscopy | 3 domains | 26; 6 M | Pre-post surgery observational | FFI, VAS | FFI pain scale scores were markedly improved at post surgery in 79% of the patients |
| FFI, 2008 | Schutte, BG | 2008 | Total ankle replacement; pain and function outcome measure | 9 items | 47; 16 M | Pre-post surgery | FFI-Dutch, Likert | Total scores improved at post-surgery |
| FFI, 2008 | Ward, CM | 2008 | Reconstruction; Validation of SF 26 with FFI | 18 items | 25; 14 M | Pre-post surgery | FFI, VAS | At follow up the FFI scores were in the mid-range. The scores for smokers were worse than non-smokers, females were worse |
Table 7 Studies using foot function measures in surgical interventions (Continued)

| Study | Year | Authors | Intervention | Outcome Measures | Follow-up | Conclusion |
|-------|------|---------|--------------|------------------|-----------|------------|
| Castellani, C | 2009 | Flexible Cavovarus Charcot Marie-Tooth | Surgery-Fixation with cannulation osteosynthesis | FFI applied at mean age of 41.5 years after 26.1 yrs follow-up | 3 domains | Useful |
| Bonnin, MP | 2009 | Flexible Arthroplasty | Surgery – Total ankle arthroplasty; Correlations of FAAM (foot and ankle ability measure) | FFI was applied at 3.8 yrs after implants removal | 3 domains | Useful |
| Potter, MQ | 2009 | Flexible Arthroplasty | Surgery-Intraarticular fracture of the Calcaneus; Correlation with AOFAS hind foot scores | Pre-post surgery pre at pre-surgery FAAM and FFI was applied, and also at 53.8 ±29 months (12–125) post-surgery | 3 domains | Useful |
| Aurich, M | 2010 | Flexible Arthroplasty | Surgery-Arthroscopic chondrocyte implant; Correlation with AOFAS hind foot scores and Core Scale of the foot and ankle module of the Academy of Orthopedic Surgeon (AAOS) | FFI VAS | 3 domains | &nbsp; |

Mean age: 15 (Range: 8.7-25) | FFI activity limitation and disability scores were correlated with SF-36 physical component scores. | &nbsp; |

Dx: Flexible Cavovarus Charcot Marie-Tooth | Location: USA | &nbsp; |

N: 21; 11 Male | Retrospective observational | &nbsp; |

Dx: Transitional fracture of distal tibia | Age 13.7 (1.4) | &nbsp; |

Location: Austria | &nbsp; | &nbsp; |

N: 140; 50 Male | Pre-post surgery pre at pre-surgery FAAM and FFI was applied, and also at 53.8 ±29 months (12–125) post-surgery | &nbsp; |

Mean age: 60.9 (Range: 26–90) | &nbsp; | &nbsp; |

Dx: OA: 100 RA: 40 | &nbsp; | &nbsp; |

Location: France | &nbsp; | &nbsp; |

N: 73; 52 Male | Retrospective observational FFI applied at follow up of 12.8 years (5–18.5) | &nbsp; |

Dx: Calcaneal fracture | &nbsp; | &nbsp; |

Location: USA | &nbsp; | &nbsp; |

N: 18; 13 Male | Retrospective observational FFI was applied at pre-arthroscopy and at follow-up, with mean duration of 19 months | &nbsp; |

Mean age: 29.2 (SD 10.2 years) | &nbsp; | &nbsp; |

Limitation: Use of FFI measures with &nbsp; | &nbsp; | &nbsp; |
Table 7 Studies using foot function measures in surgical interventions (Continued)

| Study | Authors | Year | Intervention | Patient Details | Measurement | Outcome |
|-------|---------|------|--------------|----------------|-------------|---------|
| FFI, 2010 | Van der Heide, HJL | Surgery-Correction pes cavo varus; Validation AOFAS lesser toe module | N: 39; 6 Male | Pre-post surgery; FFI applied at pre-surgery and 40 month post-surgery | FFI-Dutch | VAS |
| | | | | Mean age: 59 (Range: 29–81) | | |
| | | | | Location: Australia | | |
| | | | | Conclusion: useful | | |
| FFI, 2010 | Kroon, M | Surgery-Correction pes cavo varus; Validation AOFAS hind foot scale | N: 15; 8 Male | Pre-post surgery FFI applied at pre and 50 month post surgery | FFI-Dutch | Likert |
| | | | | Mean age: 40 (SD 14) | | |
| | | | | Location: Netherlands | | |
| | | | | Conclusion: useful | | |
| FFI, 2010 | Van Doeselaar, DJ | Surgery-Fusion of MTP; Correlation with VAS pain and satisfaction | N: 62 | Pre-post surgery; FFI applied at pre-surgery and 12 month post-surgery | FFI Dutch; Likert |
| | | | | 2 groups | |
| | | | | Dx: H rigidus; N: 27; 9 Male | |
| | | | | Mean age: 58 (Range: 42–72) | |
| | | | | Dx: H valgus; N: 35; 6 Male | |
| | | | | Mean age: 61 (Range: 37–76) | |
| | | | | Location: The Netherlands | |
| | | | | Conclusion: useful | |
| FFI, 2010 | Doets, HC | Surgery-Salvage arthrodesis for failed TAA; Correlating with AOFAS and VAS pain scale | N: 18; 4 Male | Retrospective observational FFI applied at follow up, 3–12 years | FFI-Dutch | 5 point rating scale |
| | | | | Mean age: 55 (Range: 27–76) | |
| | | | | Location: Netherlands | |
| | | | | Conclusion: useful | |
| FFI, 2010 | Niki, H | Surgery-TMT fusion and osteotomy; Concurrent assessment of FFI and SF-36 and Japanese Society for Surgery of the Foot and Ankle Score | N: 30; 1 Male | Pre-post surgery FFI was applied at pre-surgery and at 36 mos follow-up | FFI | VAS |
| | | | | Mean age: 53.6 (Range: 45–67) | |
| | | | | Location: Japan | |
| | | | | Conclusion: useful | |
Table 4 displays the versatility of the FFI with all 3 domains and FFI Subscales and FFI-R uses across the studies. This shows that clinicians and researchers were choosing the FFI scales depending on the nature of their studies. Among the various scales of the FFI, we found the FFI with all 3 domains (full scale), the FFI pain subscale only, and a combination of the pain and disability subscales to be the most frequently used, whereas the FFI-R was the least frequently used. The Dutch adaptation of the FFI, the FFI-5pts, was mostly used in the Netherlands as an outcome measure in studies of many surgical interventions.

In summary, the FFI with all 3 domains, or as subscales, was frequently chosen as a measurement instrument across various studies and countries and among various age groups and sexes, for the assessment of acute and chronic foot and ankle conditions.

Objective 2: Uses of the FFI and FFI-R in the field of foot health research

The uses of the FFI and FFI-R are provided in detail in Tables 5, 6, 7, 8, 9, and 10. Table 12 describes the study types, the name of the instruments, and the first author’s
| Instrument | 1st Author | Study and objective | Population (N, Sex, Age, Dx, location) | Methods & Analyses | Items/ Domains/ Subscales | Measurement scale | Summary evaluation |
|------------|------------|---------------------|----------------------------------------|-------------------|--------------------------|-----------------|-------------------|
| FFI, 1995  | Budiman-Mak, E [74] | Outcome measure of orthotic intervention in hallux valgus deformity | N=102 | RCT double blind Intent to Treat Analysis FFI applied at baseline and each follow up visit | FFI | VAS | This study suggest that foot orthosis can prevent or slowed the progression of hallux valgus deformity |
|            |            |                     | Treatment group (N: 52)                |                   |                          |                 |                   |
|            |            |                     | Mean age: 60.2 (SD 10.6)               |                   |                          | 23 items        |                   |
|            |            |                     | Male: 46 (88.5%)                      |                   |                          | 3 domains       |                   |
|            |            |                     | Control group (N:50)                  |                   |                          |                 |                   |
|            |            |                     | Mean age: 58.8 (SD 11.9)               |                   |                          |                 |                   |
|            |            |                     | Male: 43 (86%)                        |                   |                          |                 |                   |
|            |            |                     | DX: RA                                |                   |                          |                 |                   |
|            |            |                     | Location: USA                         |                   |                          |                 |                   |
|            |            |                      |                                        |                   |                          |                 |                   |
| FFI, 1996  | Conrad, KJ [70] | Outcome measure-Pain and function measures | N:102 | RCT double blind Post-test Random effect model for longitudinal data | FFI | VAS | This study showed no benefit on pain and disability measures between treatment group and placebo group |
|            |            |                     | Treatment group (N: 52)               |                   |                          |                 |                   |
|            |            |                     | Mean age: 60.2 (SD 10)                |                   |                          | 23 items        | Conclusion: useful |
|            |            |                     | 46 male                               |                   |                          | 3 domains       |                   |
|            |            |                     | Control group (N:50)                  |                   |                          |                 |                   |
|            |            |                     | Mean age: 58.8 (SD11.9)                |                   |                          |                 |                   |
|            |            |                     | 43 male                               |                   |                          |                 |                   |
|            |            |                     | DX: RA                                |                   |                          |                 |                   |
|            |            |                     | Location: USA                         |                   |                          |                 |                   |
| FFI, 1997  | Caselli, MA [77] | Outcome measure - Effectiveness of the intervention | N: 34; Mean age: 43 (28–59) 12 male | RCT, not-blinded FFI was applied at baseline and at 4 weeks | FFI | Categorical rating scale | 58% (11/19) of participants showed improvement in pain scores Conclusion: useful |
|            |            |                     | Group 1: Group with magnet (N: 19)    |                   |                          |                 |                   |
|            |            |                     | Group 2: Group with no magnet (N: 15) |                   |                          | 23 items        |                   |
|            |            |                     | DX: Heel pain                         |                   |                          | 3 domains       |                   |
|            |            |                     | Location: USA                         |                   |                          |                 |                   |
| FFI, 1997  | Caselli, MA [68] | Outcome measure - Effectiveness of the intervention | N: 35; Mean age: 42 (23–65) 18 male | RCT not blinded FFI was applied at baseline and at 4 weeks | FFI | Categorical rating scale | FFI scores improved at 4 weeks reported as the following: |
| FFI, 1999 | Pfeffer, G [78] | Outcome measure – primary interest is in pain subscale outcome at 8 weeks | N: 236; Mean age: 47 (23–81); 160 male | FFI VAS rating scale | Pain subscale scores improved at 8 weeks |
|------------|-----------------|---------------------------------------------------------------------------|----------------------------------------|---------------------|-----------------------------------------|
| Group 1: Stretching only (N: 39) | Mean age: 47 (25–81) 11 male | 23 items | 23 | Pain change scores controlled for covariates. Results are reported as the following: |
| Group 2: Custom orthoses & stretch (N: 34) | Mean age: 48.5 (23–69) 11 male | 3 domains | Group 1: -17.2 |
| Group 3: Silicon & stretch (N: 51) | Mean age: 49.5 (30–75) 17 male | 3 domains | Group 2: -16.9 |
| Group 4: Rubber & stretch (N: 43) | Mean age: 44 (27–69) 11 male | 3 domains | Group 3: -23.9 |
| Group 5: Felt & stretch (N:42) | Mean age: 48 (26–76) 13 male | 3 domains | Group 4: -24.5 |
| Dx: Proximal plantar fasciitis | | | Group 5: -20.2 |
| Location: USA | | | Conclusion: useful |

| FFI, 2001 | Slattery, M [82] | Outcome measure – effectiveness of the intervention | N: 46; Mean age: 24 (6.2) Sex not reported | FFI VAS rating scale | FFI scores of pain and disability subscales markedly improved at 6 weeks |
|------------|-----------------|---------------------------------------------------------------------------|----------------------|---------------------|-------------------------------------------------|
| Dx: Hemophilic foot and ankle | | 23 items | 23 | Conclusion: useful |
| Year | Author | Study Design | Interventions | N | Sex | Mean Age | Follow-up | Outcome Measure | Results |
|------|--------|--------------|---------------|---|-----|----------|------------|-----------------|---------|
| 2002 | Gross, MT | FFI, 2002 | Outcome measure – Effectiveness of the intervention correlation with 100 meter walk and VAS pain scale | 15; 8 male | | | Pre-post test design FFI was applied at baseline and post orthosis at 12–17 days | FFI 18 items Pain and disability scales | Pain and disability improved. The author suggested to modify FFI items if FFI will be used for plantar fasciitis. |
| 2002 | Woodburn, J | FFI, 2002 | Outcome measure – effectiveness of the intervention | 98; Orthosis/ vsControl | RCT double blind; 30 months study, FFI was applied at 3, 6, 12, 18, 24, and 30 months | | FFI | FFI scores improved at the completion of the RCT |
| 2005 | Powell, M | FFI, 2005 | Outcome measure – Validation of The Pediatric Pain VAS Questionnaires, Pediatric quality of life (PedQOL) inventory, physical function scale | 40; Custom orthoses: N: 15; 2 Male Mean age: 12.14 | RCT 3 arms, Single blinded | | FFI | The largest improvement of FFI scores was in the custom orthoses. VAS scoring appears applicable in children |
| 2006 | Magalhaes, E | FFI, 2006 | Outcome measure – Concurrent measure with Health | 36; 5 Male | Prospective observational | | FFI | FFI scores in pain, disability, activity limitation improved; no |
| Assessment Questionnaires (HAQ) | Orthosis N: 28 | 2 treatment groups; 6 months trial | 23 items | Correlations with HAQ scores | Conclusion: useful |
|---------------------------------|---------------|-----------------------------------|----------|-----------------------------|-------------------|
| Sham N: 8                       | FFI was applied at baseline, 30, 90, and 180 days | 3 domains |                       |                     |                   |
| Mean age: 46 (32–68) RA years 11 (1–34) |                               |                     |                       |                       |                   |
| Location: Brazil                |                               |                     |                       |                       |                   |
| FFI, 2007 Williams, AE [71]     | Outcome measure – Concurrent measure with FHSQ for designed shoes intervention | N: 80; 35 male; Age: N/A | RCT single blinded; 12 weeks trial. FFI was applied at baseline and 12 weeks; N:34 completed the study | FFI VAS rating scale | Both scores of FFI and FHSQ were improved at 12 weeks |
| Group 1: Designed shoes (N: 40); 11 male |                               | 23 items | Between groups general health was unchanged |                       |                   |
| Group 2: Traditional shoes (N: 40); 19 male |                               | 3 domains |                       |                       |                   |
| RA 17 years (14.4 yrs) |                               |                       |                       |                       |                   |
| Dx: Hallux valgus              |                               |                       |                       |                       |                   |
| Location: UK                   |                               |                       |                       |                       |                   |
| FFI, 2008 Lin, JL [81]          | Outcome measure – Validation with AOFAS VAS pain scale SF-36 | N: 32; 6 male | Observational 7–10 years (mean 8.8 years); FFI was applied at the end of the observation | FFI VAS rating scale | FFI scores for pain and disability were improved and well correlated with AOFAS scores |
| Dx: Stage II posterior tibialis tendon dysfunction (PTTD) |                               |                       |                       |                       |                   |
| Location: USA                  |                               |                       |                       |                       |                   |
| FFI, 2009 Cho, NS [72]          | Outcome measure – Validation with VAS pain scale | N: 42; Semi-rigid insole: N: 22; 0 male | RCT single blinded 6 month trial FFI was applied at baseline and 6 month. At 6 months N34 completed the study | FFI VAS rating scale | Semi-rigid insole group showed markedly improved FFI scores |
|                               | 11fore foot/11 hind foot | 23 items |                       |                       |                   |
| Mean age: 48.7 (SD=11.6)        |                               | 3 domains |                       |                       |                   |
| Soft insole: N: 20; 0 male 11 fore/10 hind foot |                               |                       |                       |                       |                   |
| Mean age: 48.7 (SD=11.7)        |                               |                       |                       |                       |                   |
| Study | Author | Country | Diagnosis | Sample Size | Outcome Measure | Intervention Duration | Foot Function Instrument | VAS Rating Scale | Conclusion |
|-------|--------|---------|------------|-------------|------------------|----------------------|------------------------|-----------------|------------|
| FFI, 2009 | Novak, P [84] | Korea | RA foot deformity, hind or forefoot | N: 40; Mean age: 56.23; 2 male | Correlation with 6 minute walk time | RCT double blinded 6 months trial FFI was applied at baseline visits 1, 2, and 3 at 6 months | FFI | | Pain improved correlation with 6 minute walk time was moderate |
| FFI, 2009 | Baldassin, V [35] | Slovenia | RA | N: 142; Custom Orthosis: N=72 | Pain relief | RCT double blind; 8 weeks trial. FFI was applied at 4 and 8 weeks | FFI | | Less pain was observed in both groups but no significant differences between groups |
| FFI-R, 2009 | Rao, S [75] | Brazil | Midfoot arthritis | N: 20; 0 male | FFI-R scores translated to clinical measure MDC90, Correlation with medial mid-foot pressure loading | Intervention 4 weeks FFI-R was applied at pre and post intervention Statistician was blinded from data sources | FFI-R | Likert | Total FFI-R scores improved correlated with significant reduction in pressure loading of the medial aspect of the midfoot |
name and the reference number. The studies are grouped by how the instruments were used and ordered chronologically within group.

**Measurement, validation and cultural adaptation**

Table 12 describes the utility of the FFI and FFI-R in studies of foot function measures and includes 17 articles. **Category A New Instruments.** Includes four articles in which foot health measures are described including the original FFI [7], the FFI-R [11]. The FFI Side to Side was derived from pain and disability subscales of the FFI [23]. The Ankle Osteoarthritis Scale (AOS) [24]; measured foot problems related to foot and ankle osteoarthritis. Agel et al. [25] modified the rating scale of the FFI pain and function subscales from the visual analog rating scale (VAS) to the Likert categorical scale; this modification was tested in a sample of individuals with non-traumatic foot complaints, and the metric of the Likert scale. The studies are grouped by how the instruments were used and ordered chronologically within group.

**Table 8 Studies using foot function measures in orthotic intervention (Continued)**

| Study | Outcome measure | Intervention | FFIR | Likert | Validation | Conclusion |
|-------|-----------------|--------------|------|--------|------------|------------|
| FFI-R, 2010 Rao, S [76] | Outcome measure – Clinical measure MDC 90 validation with segmental foot kinematic values | N: 30; 2 male | FFI-R was applied at pre and post intervention | FFIR | Likert | Full length foot orthoses reduced motion of the 1st metatarsophalangeal joint and was significantly correlated with FFIR scores |
| Welsh, BJ [73] | Outcome measure – validation with foot kinematic values VAS | N: 32; 6 male | Case series | FFI | VAS rating scale | FFI pain subscale significantly improved and met the criteria of equivalence to analgesic response. This pain reduction was not correlated with that of the biomechanical changes of the 1st metatarsophalangeal joint. |
| Clark H [85] | Outcome measure – Orthosis reduced pain and disability and correlated with gait parameter | N: 41; Gender not reported | RCT single blind 16 weeks trial. FFI was applied at baseline, 8 and 16 weeks | FFI | VAS rating scale | FFI scores were improved in orthoses and simple insole groups but the intervention did not improve gait parameter. |

**Notes:**
- MDC: Minimal detectable change
- VAS: Visual analog scale
- FFI: Foot Function Index
- FFIR: Full-length Foot Function Index Revised
| Instrument                  | 1st Author         | Objective                                      | Population (N, Sex, Age, Dx, location) | Analysis                                                                 | Items/ domains/subscales | Response type | Summary evaluation                                      |
|-----------------------------|--------------------|------------------------------------------------|----------------------------------------|---------------------------------------------------------------------------|---------------------------|---------------|---------------------------------------------------------|
| Foot Function Index, 2005   | Cui, Q [86]        | Improvement in pain and function               | N: 5; Mean age: 40 (range: 25–54); 3 male | Retrospective study; Follow-up 24 months (16–30 months). FFI was applied at pre and at post treatment | FFI VAS                   | FFI scores improved on 3 out of 5 patients post surgery.|
|                             |                    | Cortisone injection and arthroscopic surgery   | Dx: Post traumatic ankle adhesive capsulitis |                                                                          |                           |               | Conclusion: useful                                      |
|                             |                    | Location: USA                                  |                                        |                                                                          |                           |               |                                                          |
| Foot Function Index, 2005   | Di Giovanni, BF [87]| Reduction of foot pain Stretching exercise and wearing foot insert | N: 101; 33 male                          | Randomized clinical Trial Longitudinal mixed-model analysis of covariance FFI was applied at baseline and at 8 weeks (N=82, A=46, B=36). At 2 years (N=66, A=39, B=27) | FFI VAS                   | FFI pain scores improved at 2 weeks and much improved at 2 years |
|                             |                    | Mean age: 45 (range: 23–60)                    |                                        |                                                                          |                           |               | Group A had a better scores than B                      |
|                             |                    | Group A: Plantar fascia stretching             |                                        |                                                                          |                           |               | Conclusion: useful                                      |
|                             |                    | Group B: Achilles tendon stretching            |                                        |                                                                          |                           |               |                                                       |
|                             |                    | DX: Plantar fasciitis                          |                                        |                                                                          |                           |               |                                                       |
|                             |                    | Location: USA                                  |                                        |                                                                          |                           |               |                                                       |
| Foot Function Index, 2009   | Kulig, K [88]      | Validation of physical activity scale (PAS) and 5 minutes walk test, and simple heel raise test | N: 10; Gender: NA                       | Exercise intervention; 10 weeks Follow up: 6 months. FFI was applied at baseline, 10 weeks and 6 months | FFI VAS                   | FFI pain and function subscales were used to monitor pre- and post-intervention outcomes. |
|                             |                    | Mean age:52.1 (SD6.5)                          |                                        |                                                                          |                           |               | Conclusion: useful                                      |
|                             |                    | DX: Posterior tibial tendon dysfunction         |                                        |                                                                          |                           |               |                                                       |
|                             |                    | Location: USA                                  |                                        |                                                                          |                           |               |                                                       |
| Foot Function Index, 2010   | Rompe, JD [89]     | Outcomes: Change scores between observations. Stretching and shock wave therapy | N=54; 18 male                           | Randomized parallel treatment 15 months trial. Intend to treat analysis FFI was applied at baseline, 4 and 15 months | FFI VAS                   | FFI pain scores were better in stretching exercise group |
|                             |                    | Mean age: 53.1 (SD =27.7)                      |                                        |                                                                          |                           |               | Conclusion: useful                                      |
|                             |                    | Dx: Plantar Fasciotomy                         |                                        |                                                                          |                           |               |                                                       |
|                             |                    | Location: Germany                              |                                        |                                                                          |                           |               |                                                       |
| Instrument | 1st Author | Study and objective | Population (N, Sex, Age, Dx, location) | methods & analyses | Items/domains/subscales | Response type | Summary evaluation |
|------------|------------|---------------------|--------------------------------------|-------------------|--------------------------|---------------|-------------------|
| FFI, 2004  | Novak, P [4] | Epidemiology of Type II Diabetes Mellitus | Correlation of pain score with 6 minute walk time; Comparing intergroup pain score | Total N: 90; 3 groups; Cross-Sectional study | VAS scale | FFI | High pain score correlated with shorter distance walk, group with Type II diabetes neuropathy with symptoms showed the highest pain scores.  
Neuropathy with symptoms  
N: 30 Mean age 64.87 (SD=11)  
20 male  
Neuropathy, no symptoms  
N:30; Mean age: 64.87 (SD=11)  
20 male;  
Healthy volunteers  
N: 30; Mean age: 64.87 (SD=11)  
20 male; | 9 items | Conclusion: useful |
| FFI, 2004  | Williams, AE [90] | Epidemiology Rheumatic diseases | To assess foot health status | N: 139; 39 male | Cross sectional study | VAS scale | FFI scores showed a high prevalence of foot and ankle pathologies, which indicated the need of podiatry care.  
Age: NA  
Inflammatory and degenerative joint diseases  
UK | 23 items | Conclusion: useful |
| FFI, 2006  | Williams, AE [91] | Epidemiology of Paget diseases of the foot Concurrent measures of FSI and quality of Life 12-items short form | Mean age: 74.5 (46–91) | N: 134; 64 male | Cross sectional study | VAS scale | Correlations of scores were not found between instruments.  
Mean age: 74.5 (46–91) | 23 items | Conclusion: not useful |
| FFI, 2006  | Rosenbaum, D [95] | Plantar sensitivity assessment | Mean age: 55 (SD=9.9) RA; 9.6 (SD=7) | N:25; 2 male | Observational study | VAS scale | FFI was to evaluate foot sensation related to RA.  
UK | 23 items | Conclusion: useful |
| Year  | Study | Country | Objective | Population | Design | Measures | Results |
|-------|-------|---------|-----------|------------|--------|----------|---------|
| 2008  | Schmeigel et al. | Germany | Evaluate the correlation of painful walking and loss of sensitivity of the plantar surface of the foot in rheumatoid arthritis. | N: 112; Mean age: 55 (SD=11) | Observational | FFI, VAS scale | Higher FFI scores correlated with pedograph scores. Conclusion: useful. |
|       |       |         | To evaluate the function and pedographic impairment | RA1: N: 36; HAQ scores 0–1 |         |          |         |
|       |       |         | Correlation of foot pain and pedograph | 3 male; Mean age: 50.6 (SD=10.5) |         |          |         |
|       |       |         | | RA2: N: 38 HAQ scores 1.1-2 | | | |
|       |       |         | | 1 male; Mean age: 55.2 (SD=10.4) | | | |
|       |       |         | | RA3: N: 38 HAQ scores 2.1-3 | | | |
|       |       |         | | 2 male; Mean age: 58.5 (SD=11.3) | | | |
|       |       |         | Control N:20 Mean age: 53.2 (SD=12.3) | | | | |
| 2010  | Kamarli et al. | Germany | To assess the correlation of FFI scores with VAS pain scale, HAQ, Ritchie articular index, and stoke index. | N: 50; RA<3 yrs: 1 male, 5 female | Cross sectional study | FFI, VAS scale | Moderate-strong correlation of FFI scores with disease duration, VAS pain scale, HAQ, Ritchie articular index, and stoke index. No correlation with foot BMD. Conclusion: useful. |
|       |       |         | RA>3 yrs | 4 male, 40 female Mean age: 52 (SD=10.9) | Descriptive statistics | Pain scale | 9 items | |
|       |       |         | OA: N:40; 3 male | Mean age: 52.4 (SD=11.8) | | | |
|       |       |         | Healthy volunteers; N: 14 | | | | |
|       |       | Turkey | | | | | |
scale was valid. Category B FFI as Criterion Validity. Articles in this category describe several health measures and use the FFI full scale or subscales to validate these measures. Bal et al. [26] found a strong correlation of FFI scores and scores of RA functional measures: the Health Assessment Questionnaire (HAQ) and Steinbrocker Functional Class (SFC). SooHoo et al. [27] found that the Rand 36-Item Short Form Health Survey (SF-36) scores of a sample of individuals with foot and ankle disorders were moderately correlated with FFI scores and concluded that FFI scores can be used to monitor the quality of life of these patients. Shrader et al. [28] measured the stability of navicular joint alignment and found that this measure correlated well with the FFI scores of the sample. Helliwell et al. [29] developed a new measure, the Foot Impact Scale (FIS), to measure the impact of foot problems on foot health in a sample of individuals with RA; the metric of FIS was validated with the FFI and HAQ. In an RA study, van der Leeden et al. [30] reported that Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and Disease Activity Scores in 44 joints (DAS 44) were correlated with FFI scores; furthermore, this author discerns the correlations that the FFI pain subscale scores correlated with forefoot pain while the FFI function subscale scores correlated with hindfoot problems. The FFI scores were also used as validation measures of the American Orthopedic Foot and Ankle Society (AOFAS) clinical rating scales, an instrument that was widely used by foot and ankle surgeons [31]. These validation studies were reported by Baumhauer et al. [32] for the AOFAS hallux clinical rating scale and by Ibrahim et al. [33] for the AOFAS clinical rating scale, which was well to moderately correlated with FFI scores. The latter finding was based on his study with a 41% response rate in a sample consisting of 45 individuals.

Table 10 Studies using foot function measures in observational studies (Continued)

| FFI, 2010 | Goldstein, CL [94] | Foot and ankle trauma | N: 52; 31 male | Cross sectional study the mean duration post trauma 15.5 months (1 month-10 years) | FFI | VAS | There was a high correlation among FFI scores and the 5 listed instruments.
| --- | --- | --- | --- | --- | --- | --- | --- |
| Correlation of FFI, SF-12, SMFA, FAAM, AAOS, AOFAS | Mean age: 43.3 (18-85) | 9 items | Conclusion: useful |
| OA; Foot and ankle trauma | Pain scale |
| Canada |

| FFI, 2010 | Kaylak, Y [93] | Elderly men Concurrent measure with VAS pain scale, foot problem score, hind foot function scale | N: 53; 53 male | Cross sectional study | FFI | VAS scale | FFI was simple and comprehensive and was significantly correlated with hind foot function scale, and scores of timed up and go.
| --- | --- | --- | --- | --- | --- | --- |
| Mean age: 73.8 (7.08) | 23 items | Conclusion: useful |
| Foot problems | 3 domains |
| Turkey |

Table 11 Reliability and unidimensionality of the full scale, short form, and subscales

| Full scale (68 items) | Short form (34 items) | 1-11 (Pain) | 12-19 (Stiffness) | 20-39 (Difficulty) | 40-49 (Limitation) | 50-68 (Social issues) |
| --- | --- | --- | --- | --- | --- | --- |
| Person Reliability | .96 | .95 | .89 | .89 | .94 | .78 | .84 |
| Cronbach’s Alpha | .98 | .97 | .93 | .95 | .97 | .87 | .94 |

Unidimensionality Criteria

(Ratio of the raw variance explained by measures: Unexplained variance in 1st contrast ≥ 3)

| 56.8/10.6= | 60.2/15.8= | 66.7/22.1= | 67.5/34.7= | 72.7/15.5= | 63.4/19.2= | 53.6/18.1= |
| 5.4 | 3.8 | 3.0 | 1.94 | 4.69 | 3.3 | 2.96 |

Yes | Yes | Yes | No | Yes | Yes | No

1 Further inspection of the data revealed that the two-factor solution was associated with the severity of the items, where the two factors were actually low and high severity stiffness, i.e. opposite poles of the same factor. Therefore, the scale is useful as a measure of stiffness.

2 These were the results after removing item 41 (ASSISTO).

3 Approximately unidimensional.
Table 12 Summary of FFI and FFI-R uses as provided in detail in Tables 5-10

| FFI/FFI-R instrument usage | Category Name of instrument | First Author’s name [reference number] | Measurement (Details in Tables 5 & 6) |
|----------------------------|-----------------------------|----------------------------------------|--------------------------------------|
| A) New Instrument          | FFI                         | Budiman-Mak E [7]                     |                                      |
|                            | FFI-R                       | Budiman-Mak E [11]                    |                                      |
|                            | FFI-site to site            | Saag KG [23]                          |                                      |
|                            | AOS                         | Domsic RT [24]                        |                                      |
|                            | FFI Likert Scale            | Agel J [25]                           |                                      |
|                            | HAQ and SFC                 | Bal A [26]                            |                                      |
| B) FFI as Criterion Validity| SF-36                       | SooHoo NF [27]                        |                                      |
|                            | Naviculare joint alignment  | Shrader JA [28]                       |                                      |
|                            | FIS                         | Helliswell P [29]                     |                                      |
|                            | WOMAC and DAS 44            | Van der Linden M [30]                 |                                      |
|                            | AOFAS                       | Lau JT [31]                           |                                      |
|                            | AOFAS Hallux                | Baumhauer JF [32]                     |                                      |
|                            | Dutch-FFI-5pts              | Kuyvenhoven MM [3]                    |                                      |
|                            | FFI-G                       | Naal FD [34]                          |                                      |
|                            | FFI-Taiwan Chinese          | Wu SH [36]                            |                                      |
|                            | FFI- Spanish                | MAPI Institute [38]                   |                                      |

Surgeries (Details in Table 7)

a) Arthrodeses and Fusions

| Name of instrument | First Author’s name [reference number] |
|--------------------|----------------------------------------|
| FFI, FFI-Dutch,    | Lin SS [39], Grondal L [40], van der  |
|                    | Krans A [41], Stegman M [42], Vesely  |
|                    | R [43], Doets HC [44], Jung HG [45],  |
|                    | van Doseselaar DJ [46], Niki H [47]   |
| b) Arthroplasty    | Ibrahim T [48], Taranow WS [49],      |
|                    | Schutte BO [50], Bonnin MP [51]       |
| c) Fracture Care   | Vallier HA [52], Harris AM [53],      |
|                    | Potter MQ [54], Gaskill T [55]        |
| d) Reconstruction Surgery | Mulcahy D [56], Ward CM [57],  |
|                        | Schlegel UI [58], van der Heide HI [59], Kroon M [60] |
| e) Other surgery    | Watson TS [61], Daniels TR [62], Lee  |
|                    | S [63], SooHoo NF [64], Strepek S [37], |

Orthoses (Details in Table 8)

| Name of instrument | First Author’s name [reference number] |
|--------------------|----------------------------------------|
| FFI, FFI pain and  | Cui Q [86]                             |
| disability subscales|                                        |

Other interventions (Details in Table 9)

| Name of instrument | First Author’s name [reference number] |
|--------------------|----------------------------------------|
| Injection          |                                       |
| stretching exercise| DiGiovani BF [87], Kulig K [88], Rompe |
| JD [89]            |                                        |

Observational studies (Details in Table 10)

| Name of intervention | First Author’s name [reference number] |
|----------------------|----------------------------------------|
| Foot morbidities     |                                        |
| In diabetes mellitus | Novak P [4]                            |
| In rheumatic diseases| Williams AE [90], Williams AE [91]    |
| In bone mineral density | FFI pain subscale  |
| In elderly           | Kavak Y [93]                            |
| In foot post-injury  | FFI, FFI pain subscale                 |
| in rheumatoid arthritis | FFI                              |

Category C Cultural Adaptation or Translation. The first translation of the FFI was the Dutch-language instrument known as Dutch FFI-5pts [3]. The German-language translation of the instrument is the FFI-G [34]; the FFI was also translated into Brazilian Portuguese [35], Taiwan Chinese [36], Turkish [26], and Czech [37]. There was also a Spanish translation conducted by the MAPI Institute in Lyon, France [38]. These translations complied with rigorous language translation procedures; occasionally, some item adjustments of the scales were needed. In summary, the
FFI was developed with good reliability and validity; it also inspired and served as criterion validity for newer foot health measures and attracted the attention of researchers around the world, who conducted translations and adaptations of the tool into their native languages and cultures.

Table 6 is a supplement to Table 5 and displays the clinimetrics of the instruments listed in Table 5; measures were metrically good, with reliability and validity values greater than 0.7 with one exception where the pain subscale had a reliability of 0.64 [3].

**Surgical intervention**

The FFI is one of the outcome measures most frequently used by AOFAS members [31]. It was first used to measure surgical outcomes. The surgical interventions and outcomes are summarized in Table 7. There are 30 articles, categorized generally according to type and location of surgical procedure. Five distinct procedural categories were identified as follows: (a) arthrodeses within the foot or ankle [39-47], (b) arthroplasty within the foot or ankle [48-51], (c) fracture care of the foot or ankle [52-55], (d) deformity reconstruction surgery of the foot or ankle [56-60], and (e) various surgical interventions for chronic conditions [61-64]. The FFI was also used to assess outcomes of less invasive procedures, such as calcaneal spur treatment by arthroscopy [37], distal tibia repair using fixation with cannulation osteosyntheses [65], arthroscopic chondrocyte implant of the tibia and fibula [66], and surgical interventions for complex ankle injuries [67]. In summary, the FFI and the Dutch FFI-5pts appeared to be useful in measuring outcomes of various surgical procedures in children, adults, and individuals with acute, chronic, and congenital foot and ankle problems.

**Orthotic interventions**

Table 8 lists studies using foot function outcome measures in orthotic interventions in the foot and ankle. The studies assessed the impact of orthotic treatment on forefoot, midfoot, and hindfoot/ankle pathology. Orthotic treatment on the forefoot in patients with RA improved the scores for pain, disability and activities [68,69], however the scores were unchanged in the study by Conrad et al. [70]. Other studies using special shoes and shoe inserts showed symptoms of relief in hallux valgus pain [71] hindfoot and forefoot problems [72,73]; and slowing the progression of hallux valgus in early RA [74]. Midfoot studies assessing the treatment of full length orthoses on pain relief [75], and mobility were performed using the FFI-R as an outcome measures [76]. For hindfoot conditions treatment with orthoses included studies of heel pain [77], plantar fasciitis [35,78,79], stabilizing hindfoot valgus [80], correction of posterior tibialis tendon dysfunction [81], destructive hemophilic arthropathy of the foot and ankle [82] and juvenile idiopathic arthritis of the foot and ankle [83]. Shoes/shoe inserts have also been found to relieve foot and ankle pain from arthritides [84,85]. In summary, the FFI and FFI-R clearly provided useful outcome measures for orthotic management of a wide range of foot and ankle disorders.
**Medical intervention**

The FFI also was used to measure foot health outcomes associated with medical interventions (Table 9), such as cortisone injection of the ankle adhesive capsulitis [86]; the injection resulted in improved FFI pain and disability subscale scores. Di Giovanni et al. [87] measured the outcome of stretching exercises for plantar fasciitis versus Achilles tendonitis; both groups showed improvement in FFI pain subscale scores. Kulig et al. [88] used the FFI pain and disability subscales to measure the outcomes of exercise intervention in posterior tibial tendon dysfunction. Rompe et al. [89] reported the FFI pain score improved in the stretching treatment group of a randomized clinical trial using stretching and shockwave therapy to treat patients with plantar fasciopathy. Overall, the FFI was useful in measuring the outcomes of conservative interventions in chronic foot and ankle conditions.

**Observational studies**

Investigators had chosen the FFI scores or the subscale scores to determine the prevalence and disease burden of foot and ankle conditions in the general population (Table 10). Novak et al.[4] used FFI scores to evaluate type 2 diabetes with and without neuropathy and identified that group with neuropathy had worse FFI scores. Williams and Bowden [90] correlated high FFI scores to foot morbidity in rheumatic diseases, and estimated cost of care/staffing concerns for that patient subset. Williams [91] also used the FFI scores in patients with Paget’s disease and noted the impacts on plantar foot pressures, gaits, and ambulation abilities. Kamanli et al. [92] correlated the scores of the FFI and foot bone mineral density, then extrapolated these scores to that individual’s skeletal bone density. Kavak and Demitras [93] reported a strong correlation of FFI scores with the scores of VAS pain scale, foot pain scale (FPS), and hindfoot function scale (HFS) in patients with foot problems. Goldstein et al. [94] noted that FFI scores of individuals with previous foot injuries had a high correlation with 6 other foot function instruments. Rosenbaum et al. [95] found that plantar sensory impairment of the foot in patients with RA was correlated with poor FFI scores. Schmiegel et al. [96] found that pedobarograph scores of patients with RA with foot pain were correlated with poor FFI and HAQ scores. In summary, FFI scores were useful in detecting the prevalence of foot and ankle problems and as a measure of concurrent validity for other foot health measures in various chronic foot conditions.

In all, we found the FFI instrument was frequently chosen as an outcome measure of surgical, orthotic, and medical treatments, but its application was wider than we originally imagined. It was not limited to outcome measures; FFI scores were also applied in the promotion of foot health as a common public health issue and in increasing the awareness of health system administrators. The FFI was also used in the validation of newly developed foot health measures.

**Objective 3: The strengths and weaknesses of the FFI and FFI-R as reported in the literature**

**FFI**: The FFI questionnaire had good psychometric properties [97-100], and the pain subscale was sensitive to change during instrument development [13]. In a study about treatment of plantar fasciitis in individuals with chronic foot pain, SooHoo et al. [64] reported that the pain subscale of the FFI had high standard response mean (SRM) and high effect size (ES) as outcome measures of surgery in chronic foot and ankle problems. While Landorf and Radford measured the clinical ability to detect a change as minimal important difference (MID) in plantar fasciitis [101]. All these clinical measures add to the credibility of the FFI as a self-reporting measure, the FFI reflects patients’ assessment of their symptoms/health status, which directs providers about proper care planning and progress toward treatment goals. FFI is one of the most cited measures of its kind [102].

There are weaknesses of the FFI. During the development of the index, clinicians generated the questionnaire items without patient participation [13,97]; therefore, items might not fully reflect patients’ needs, might be sex biased [7], and might not be applicable to high-functioning individuals. A theoretical model was not part of the design, nor were the items related to footwear [13,103], which are essential to support the construct of this instrument. It is also lacking items for measuring quality of health and satisfaction with care; however, these items can be appended as a global statement in the questionnaire. In all, the FFI has been the most studied and widely used foot-specific self-reporting measure; however, further testing by gender, age, race, language, etc. would provide assurance of its generalizability.

**FFI-R**: The FFI-R was developed in response to criticism of the FFI and to address issues of contemporary interest. Most original items from the FFI were selected in the development of FFI-R, and new items about footwear and psychosocial factors were added, which improved its construct coverage. Patients and clinicians were involved in the generation of items. Its design closely followed the ICF theoretical model [13]; its psychometric properties are strong and are based on the IRT 1-parameter or the Rasch measurement model. It was designed to be a comprehensive measure of foot health-related quality of life, with both long and short forms [99], allowing clinicians and researchers to choose the measures they need for the intended study. Although the FFI-R did not include information on clinical ability to measure change in its development, Rao et al. [75,76] did measure the minimal detectable change (MDC) and
the effect size, in individuals with midfoot arthritis, which also added to the credibility of its metrics.

Objective 4: The newly analyzed FFI-R with improved psychometric values

The full scale and short form

For the FFI-R L (68 items) [11], person reliability was high: 0.96, respectively. In the PCA, 56.8% of the variance was explained by the measure, with only 10.6% of the variance explained by the first factor of residuals. These findings support that the full FFI-R meets the unidimensionality requirement of the Rasch model. Further, the criterion for unidimensionality was a ratio of the raw variance in the first contrast of residuals that was 5.4 (i.e., greater than 3). For the FFI-R S (34 items) [11], person reliability was 0.95, similar to the reliability estimates of the FFI-R L. The PCA of the FFI-R S revealed that unidimensionality criteria were also satisfied. This supports the use of a short form of the measure, because the item response burden on patients is lower, at 34 questions. Because this measure is as reliable as the full measure, its use is supported for clinical settings.

Subscales

All subscales of the FFI-R had strong person reliability estimates (Table 11), ranging from 0.78 to 0.94 for person reliability. The PCA indicated that unidimensionality held for each subscale, with the exception of the stiffness subscale. Further inspection of the data revealed that the two-factor solution reflected groups of the low-severity and high-severity items and was not the result of a competing factor. Unidimensionality for the limitation subscale was higher, at 34 questions. Because this measure is as reliable as the full measure, its use is supported for clinical settings.

Response category analysis

The response category analyses for each of the subscales (done after collapsing Categories 5 and 6) revealed that, for the first three subscales (pain, stiffness, and difficulty), the response categories behaved as required by the Rasch model. For the subscales of limitation (Table 11), the response category analysis (done after collapsing Categories 5 and 6) revealed that, for the first three subscales (pain, stiffness, and difficulty), the response categories behaved as required by the Rasch model. Further, the criterion for unidimensionality was a ratio of the raw variance in the first contrast of residuals that was 5.4 (i.e., greater than 3). For the FFI-R S (34 items) [11], person reliability was 0.95, similar to the reliability estimates of the FFI-R L. The PCA of the FFI-R S revealed that unidimensionality criteria were also satisfied. This supports the use of a short form of the measure, because the item response burden on patients is lower, at 34 questions. Because this measure is as reliable as the full measure, its use is supported for clinical settings.

Discussion

This review evaluated 78 eligible articles (Figure 1). In the past 20 years, it appears that the FFI and FFI-R were widely used across national and international clinical and research communities. The instruments were administered to over 4700 study participants of males and females worldwide, across age groups, with 20 different diagnoses consisting of congenital, inflammatory/degenerative, acute and chronic foot and ankle problems. The FFI was also incorporated into other newer foot health measures [23,24], and also underwent changes in the measurement scale from VAS to Likert scale such as the one conducted by Agel et al. [25]. The scale changes occurred in FFI adaptation to the Dutch [3], German [34], and Taiwanese Chinese [36] including our revised FFI-R [11] to give a few examples. The strong metrics of FFI subscales and full scale (Table 12, Category A), facilitated the investigator’s choice to use its subscale(s) or full scale in clinical or research applications as appropriate. The FFI was also frequently used as validation criterion for other foot health measures (Table 12, Category B); this validation usage has elevated the credibility of the FFI as an outcome measure for foot and ankle problems. Since the FFI was developed using CTT procedures, it is sample and content dependent, therefore its metrics were tested in many different samples, where its metrics were proven to be consistently strong. The exception was in the study of Baumhauer et al. [32] where high foot functioning was evident in the sample; therefore, investigators should exercise caution in the interpretation of this result. While the FFI was developed initially as disease specific for early RA, in later years, it was used in many non-RA foot and ankle problems and was proven to be a valid measure as well. The FFI and FFI-R were frequently used as outcome measures in surgical and clinical interventions with positive results (Tables 7, 8, 9, and 10). The FFI scores were also used in many observational studies (Table 10) and those reports might be helpful for researchers and the health system administrators in establishing a health policy. Although the FFI was extensively studied and generally received positive ratings [23,29,102], we realized the need for improvement in the measures of FFI and FFI-R and have discussed this issue comprehensively under Objective 3 in this paper. We conducted a re-analysis and made improvements to the metrics and scales of FFI-R as presented in Table 11 and questionnaires FFI-R Long Form (See Additional file 1), and Short Form (See Additional file 2).

In recent articles about FFI used as outcome measures, the authors have included the clinical measures; the effect size, and standard response mean [64], and minimal important difference [101], while Rao et al. reports minimal
detectible change and effect size of the FFI-R [75], all these have increased the credibility of the clinical use of the FFI to help in power analysis and sample size estimation for future studies.

Limitations of this review
Our literature search was limited to publications written in the English language and covered only publications until 2010; therefore, this might exclude the FFI- and FFI-R–related published articles not written in English, as well as those more recent articles published in English.

Conclusions
The FFI pioneered measuring foot health. This instrument has been tested through time and adapted in its measures as it was frequently used in full scales or subscales to measure outcomes in various clinical practice or research studies. The FFI has also had a role in shifting the paradigm from a reliance on physical and biochemical findings as outcomes to the use of outcomes that are relevant to patients. Thus, the measure established patient-centered, valid, reliable, and responsive hard data endpoints. The rating scales also underwent changes; for practicality and user-friendliness in clinical and research settings. The FFI was recognized as a valid instrument and used as a validation criterion of other measures. It was adapted and translated into multiple languages. It was applied to all age groups, across genders and was useful in measuring varied medical and surgical conditions.

In realizing the scope of FFI applications, we acknowledge the contributions of friends and colleagues around the world who not only used the FFI in their studies but also made adaptations and translations to make the FFI a versatile instrument in promoting and maintaining foot health. The FFI-R has good psychometric properties and is available in long and short forms for ease of clinical use. In response to findings in this review, we conducted a rigorous analysis to strengthen the metrics of the FFI-R and changed the rating scales to be more user-friendly and practical.

Both the FFI and FFI-R are in the public domain and permission to use them is free of charge. They are available from the developers of these instruments and from the AOFAS web site. These instruments are self-administered and are written at an eighth-grade reading level. The FFI scores are interpreted as 0%-100% for each subscale and the overall score. Higher FFI and FFI-R scores indicate poor foot health and poor foot health-related quality of life. The FFI and FFI-R put minimal burden on respondents and the questionnaires are not emotionally sensitive. The administrative burden is also minimal and it does not require formal training to score or to interpret [104]. Translations and adaptations are available in Dutch [3], Taiwan Chinese [36], German [34], Turkish [26], Brazilian Portuguese [35], and Spanish [38].

This review attests to the widespread use of foot health measures, and we have noticed the advancement of foot health in general across diagnoses. It has been a privilege for us to serve patients, clinicians, and researchers to fulfill the mission in improving foot health through the use of the FFI and FFI-R. These instruments are available for users, and can be downloaded as they are presented as electronic files.

Additional files

**Additional file 1:** Revised FOOT FUNCTION INDEX (FFI-R).

**Additional file 2:** Revised FOOT FUNCTION INDEX (FFI-R) Short Form.

**Abbreviations**

AOAFAS: American Orthopedic Foot and Ankle Society; CTT: Classical test theory; EMBASE: Excerpta Medica Database; FFI: Foot Function Index; FFI-R: Foot Function Index Revised; EBM: Elly Budiman-Mak; FFI-R L: Foot Function Index Revised Long Form; FFI-R S: Foot Function Index Revised Short Form; HAQ: Health Assessment Questionnaire; IRT: item response theory; JM: Jessica Massa; KJC: Kendon J Conrad; Medline: Medical Literature Analysis and Retrieval System; PUBMED: public Medline; RA: rheumatoid arthritis; RMS: Rodney M. Stuck; VAS: visual analog rating scale; AAOS: American Academy of Orthopedic Surgeons; ANOVA: Analysis of Variance; AOS: Ankle Osteoarthritis Index; BMD: Bone Mineral Density; CA: Crohnbach’s Alpha; CRI: Clinical Rating Index; CV: Calcaneal Varus; DAS 44: Disease Activity Score in 44 joints of patient with rheumatoid arthritis (RA); DX: Diagnosis; EF: External Fixation Procedure; ES: Effect Size; FAQM: Foot and Ankle Ability Measure; FFI-5pts: Dutch Foot Function Index with 5 point Likert Scale; FFI-G: Foot Function Index - German Language; FHSQ: Foot Health Status Questionnaire; FSS: Foot Impact Scale; FPS: Foot Problem Score; FSI: Foot Structure Index; FX: Fracture; HFS: Hind Foot Function Scale; HMP: Hallux Metatarso-interphalangeal Joint; HR: Hallux Rigidus; ICC: Interclass Correlation Coefficient; JIA: Juvenile Idiopathic Arthritis; JRA: Juvenile Rheumatoid Arthritis; LIMP: Leiser Metatarso-interphalangeal Joint; MCS: Mental Component Score of SF-36; MDC: Minimal Detectible Change; MFA: Musculoskeletal Function Assessment; MHPQ: Manchester Foot Disability Questionnaires; MD: Minimal Important Difference; MODEMS: Musculo-skeletal Outcome Data Evaluation and Management System; MTP: Metatarsophalangeal Joint; NA: Not Applicable; OA: Osteoarthritis; PAS: Physical Activity Scale; PCS: Physical Component Score of SF-36; PedQL: Pediatric Quality of Life Scale; PF: Plantar Fasciitis; PTD: Posterior Tibialis Tendon Dysfunction; QOL -12: Quality of Life 12 items short form; RA: Ritchie Articular Index; RCT: Randomized Control Trial; SD: Standard Deviation; SF-36: Rand 36 items health survey form; SF-36 MCS: Mental Component Score of SF-36; SF-36 PCS: Physical Component Score of SF-36; SF-12: Rand 12 items short form health survey; SFC: Steinbrocker Functional Class; SMFA: Musculoskeletal Function Assessment; SRM: Standard Response Mean; SI: Stroke Index; TAA: Total Ankle Arthroplasty; TMT: Tarso Meta-metatarso Joint; UCLA: University of California - Los Angeles; WOMAC: Western Ontario MacMaster University Osteo Arthritis Index.

**Competing interests**

The authors declare that they have no competing interests.

**Authors’ contributions**

EBM, KJC, have contributed in drawing the concept and design of this paper, EBM initiated the literature search, reviewed, scrutinized them, and collected the abstracts and organized into tables. KJC, RMS and JM reviewed the tables and all authors participated in drafting the manuscript. KJC and JM also reanalyzed the original FFI-R data and revised the subscales and FFI-R response categories. All authors participated in revising the manuscript and have given final approval of the version to be published.
Acknowledgements
The authors gratefully acknowledge the support from the Center for Management of Complex Chronic Care, Hines VA Hospital, Hines, IL, USA. The paper presents the findings and conclusions of the authors; it does not necessarily represent the Department of Veterans Affairs or Health Services Research and Development Service. We are also grateful to Cindi Fandacca and the Hines VA medical library staff for assisting in the literature search, Madeline Thornton for assisting in designing the tables, Leanneh Sarlo and Mary Reidy for editing the manuscript.

Author details
1 Center for Management of Complex Chronic Care, Staff Physician, Medical Service, Hines VA Hospital, 5000 South 5th Ave, Hines, IL 60141-3030, USA. 2Department of Medicine Loyola University Stritch School of Medicine, Loyola University of Chicago, Maywood, IL 60513, USA. 3Health Policy and Administration (MC 923) School of Public Health University of Illinois at Chicago, 1603 West Taylor Street, Chicago, IL 60612-4394, USA. 4University of Illinois at Chicago School of Public Health (MC923), 1603 West Taylor Street, Chicago, Illinois 60612, USA. 5Department of Orthopaedic Surgery, Loyola University Stritch School of Medicine, Loyola University of Chicago, 2160 South First Ave, Maywood, IL 60153, USA. 6Surgical Service, Hines VA Hospital, 5000 South 5th Ave, Hines, IL 60141-3030, USA.

Received: 2 November 2012 Accepted: 11 January 2013 Published: 1 February 2013

References
1. Bonenfant F, Ferrucci L, Guralnik JM, Gangemi S, Baroni A: Foot pain and disability in older persons: an epidemiologic survey. J Am Geriatr Soc 1995, 43:479–484.
2. Leveille SG, Guralnik JM, Ferrucci L, Hirsch R, Simonsick E, Hochberg MC: Foot pain and disability in older women. Am J Epidemiol 1998, 148:657–665.
3. Kuyvenhoven WW, Gorst KJ, Zuijkhoff P, Budiman-Mak E, Consad KJ, Post MW: The Foot function index with verbal rating scales (FFI-VRS); a clinimetric evaluation and comparison with the original FFI. J Rheumatol 2002, 29:1023–1028.
4. Novak P, Burger H, Marinicic C, Meh D: Influence of foot pain on walking ability of diabetic patients. J Rehabil Med 2004, 36:249–252.
5. Menz HB, Lord SR: The contribution of foot problems to mobility impairment and falls in community-dwelling older people. J Am Geriatr Soc 2001, 49:1651–1656.
6. Menz HB, Lord SR: Foot pain impair balance and functional ability in community-dwelling older people. J Am Podiatr Med Assoc 2001, 91:222–229.
7. Budiman-Mak E, Conrad KJ, Roach KE: The Foot Function Index: a measure of foot pain and disability. J Clin Epidemiol 1991, 44:561–570.
8. Nunnally J, Bernstein I: Psychometric Theory. New York: McGraw-Hill; 1994.
9. Bennett PJ, Patterson C, Wearing S, Baglioni T: Development and validation of a questionnaire designed to measure foot-health status. J Am Podiatr Med Assoc 1998, 88:149–428.
10. Landorf KB, Keenan AW: An evaluation of two foot-specific, health-related quality-of-life measuring instruments. Foot Ankle Int 2002, 23:538–546.
11. Budiman-Mak E, Conrad K, Stuck R, Matters M: Theoretical model and Rasch analysis to develop a revised Foot Function Index. J Foot Ankle Res 2006, 27:519–527.
12. International Classification of Impairments, Disabilities and Handicaps; [www.who.int/entity/classification/icf/en/]
13. Walsmey S, Williams AE, Ravey M, Graham A: The rheumatoid foot: a systematic literature review of patient-reported outcome measures. J Foot Ankle Res 2010, 3:12.
14. line: J. M. In: Winstons Rasch Measurement (Version 3.72.0); 2011.
15. line: J. M. Structure in Rasch residuals–Why principal components analysis (PCA)? Rasch Measurement Transactions 1998, 1:636.
16. line: J. M. Detecting multidimensionality; which residuals data-type works best? J Outcome Meas 1998, 2:266–288.
17. line: J. E. W. Detecting and evaluating the impact of multidimensionality using item fit statistics and principal component analysis of residuals. J Appl Meas 2002, 3:205–231.
18. Reckase M: Unifactor latent trait model applied to multifactor tests: results and implications. J Educ and Behav Stat 1979, 4:207–230.
19. Embretson SE, Reise SP: Item response theory for psychologists. Mahwah, NJ: Lawrence Erlbaum Associates Inc; 2000.
20. Bond TG, Fox CM: Applying the Rasch model: fundamental measurement in the human sciences. Mahwah, NJ: Lawrence Erlbaum Associates; 2007.
21. Lineac JM: Investigating rating scale category utility. J Outcome Meas 1999, 3:103–122.
22. Lineac JM: Optimizing rating scale category effectiveness. J Appl Meas 2002, 3:245–256.
23. Saiz KG, Saltzman CL, Brown CK, Budiman-Mak E: The Foot Function Index for measuring rheumatoid arthritis pain: evaluating side-to-side reliability. Foot Ankle Int 1996, 17:506–510.
24. Domsic RT, Saltzman CL: Ankle osteoarthritis scale. Foot Ankle Int 1998, 19:466–471.
25. Agel J, Beskin JL, Brage M, Guyton GP, Kadel NJ, Saltzman CL, Sands AK, Sangeorzan BJ, Soocho NF, Stroud CC, et al: Reliability of the Foot Function Index: a report of the AOFAS Outcomes Committee. Foot Ankle Int 2005, 26:962–967.
26. Bal A, Aydog E, Aydog ST, Cakci A: Foot deformities in rheumatoid arthritis and relevance of foot function index. Clin Rheumatol 2006, 25:671–675.
27. Soocho NF, Samimi DB, Vyas RM, Bozder T: Evaluation of the validity of the Foot Function Index in measuring outcomes in patients with foot and ankle disorders. Foot Ankle Int 2006, 27:32–42.
28. Sharde JA, Popovich JM Jr, Gracey GC, Danoff JV: Navicular drop measurement in people with rheumatoid arthritis: interrater and intrarater reliability. Phys Ther 2005, 85:656–664.
29. Helliwell P, Neay N, Gilworth G, Redmond A, Silade A, Tennant A, Woodburn J: Development of a foot impact scale for rheumatoid arthritis. Arthritis Rheum 2005, 53:418–422.
30. VanderLeeden M, Steultjens M, Dekker JH, Prins AP, Dekker J: Forefoot joint damage, pain and disability in rheumatoid arthritis patients with foot complaints: the role of plantar pressure and gait characteristics. Rheumatology (Oxford) 2006, 45:465–469.
31. Lau JT, Mahomed NM, Schon LC: Results of an Internet survey determining the most frequently used ankle scores by AOFAS members. Foot Ankle Int 2005, 26:479–482.
32. Baumhauer JF, Navoczenski DA, DiGiovanni BF, Wilding GE: Reliability and validity of the American Orthopaedic Foot and Ankle Society Clinical Rating Scale: a pilot study for the hallux and lesser toes. Foot Ankle Int 2006, 27:1014–1019.
33. Ibrahim T, Beiri A, Azzabi M, Best AI, Taylor GJ, Menon DK: Reliability and validity of the subjective component of the American Orthopaedic Foot and Ankle Society clinical rating scales. J Foot Ankle Surg 2007, 46:65–74.
34. Nair FD, Impellizzeri FM, Huber M, Rippstein PF: Cross -cultural adaptation and validation of the Foot Function Index for use in German -speaking patients with foot complaints. Foot Ankle Int 2008, 29:1222–1228.
35. Balassin V, Gommes CR, Beraldo PS: Effectiveness of prefabricated and customized foot orthoses made from low-cost foam for noncomplicated plantar fasciitis: a randomized controlled trial. Arch Phys Med Rehabil 2009, 90:701–706.
36. Wu SH, Liang HW, Hou WH: Reliability and validity of the Taiwan Chinese version of the Foot Function Index. J Famos Med Assoc 2008, 107:111–118.
37. Stropek S, Dvorak M: Arthoscopic treatment for calcaneal spur syndrome. Acta Chi Orthop Traumatol Cech 2008, 75:363–368.
38. Foot Function Index Spanish Translation, [www.proqol.org]
39. Lin SS, Bono CM, Treuting R, Shereff MJ: Reliability of the Navicular osteotomy using bone grafting and pin fixation. Foot Ankle Int 2000, 21:742–748.
40. Gondal L, Hedstrom M, Stark A: Arthrodesis compared to Mayo resection of the first metatarsalphalangeal joint in total rheumatoid foot/forefoot reconstruction. Foot Ankle Int 2005, 26:135–139.
41. van der Klaas A, Louweners JW, Anderson P: Adult acquired flexible flatfoot, treated by calcaneocuboid distraction arthrodesis, posterior tibial tendon augmentation, and percutaneous Achilles tendon lengthening: a prospective outcome study of 20 patients. Acta Orthop 2006, 77:156–163.
42. Stegman M, Anderson PG, Louwerens JW: Triple arthrodesis of the hindfoot, a short term prospective outcome study. Foot Ankle Surg 2006, 71:71–77.
43. Vesely R, Prochazka V, Vrana P, Valenta J, Savoyt J: Tibiotalocalcaneal arthrodesis using a retrograde nail locked in the sagittal plane. Acta Chir Orthop Traumatol Cech 2008, 75:129–133.
44. Doets HC, Zurcher AW: Salvage arthrodesis for failed total ankle arthroplasty. Acta Orthop 2010, 81:142–147.
94. Goldstein CL, Schemitsch E, Bhandari M, Mathew G, Petrisor BA: Comparison of Different Outcome Instruments Following Foot and Ankle Trauma. Foot Ankle Int 2010, 31:1075–1080.

95. Rosenbaum D, Schmiegel A, Meermeier M, Gaubitz M: Plantar sensitivity, foot loading and walking pain in rheumatoid arthritis. Rheumatology (Oxford) 2006, 45:212–214.

96. Schmiegel A, Rosenbaum D, Schorat A, Hiller A, Gaubitz M: Assessment of foot impairment in rheumatoid arthritis patients by dynamic pedobarography. Gait Posture 2008, 27:110–114.

97. Trevethan R: Evaluation of two self-referent foot health instruments. Foot (Edinb) 2010, 20(4):101–108.

98. Martin RL, Irrgang JJ: A survey of self-reported outcome instruments for the foot and ankle. J Orthop Sports Phys Ther 2007, 37:72–84.

99. Landorf KB, Burns J: Health Outcome Assessment. In Merriman’s Assessment of the Lower Limb. 3rd edition. Edited by Ben Y, Merriman LM. Philadelphia, PA 19103–2899: Churchill Livingstone, Elsevier Limited; 2009:33.

100. Button G, Pinney S: A meta-analysis of outcome rating scales in foot and ankle surgery: is there a valid, reliable, and responsive system? Foot Ankle Int 2004, 25:521–525.

101. Landorf KB, Radford JA: Minimal important difference: Values for the Foot Health Status Questionnaire, Foot function Index and Visual Analogue Scale. The Foot 2008, 18:15–19.

102. van der LM, Steultjens MP, Terwee CB, Rosenbaum D, Turner D, Woodburn J, Dekker J: A systematic review of instruments measuring foot function, foot pain, and foot-related disability in patients with rheumatoid arthritis. Arthritis Rheum 2008, 59:1257–1269.

103. Jannink MJ, deVries J, Stewart RE, Groothoff JW, Lankhorst GJ: Questionnaire for usability evaluation of orthopaedic shoes: construction and reliability in patients with degenerative disorders of the foot. J Rehabil Med 2004, 36:242–248.

104. Rogers JC, Irrgang JJ: Measures of Adult Lower Extremity Function. Arthritis Rheum 2003, 49:567–584.

Cite this article as: Budiman-Mak et al: A review of the foot function index and the foot function index – revised. Journal of Foot and Ankle Research 2013 6:5.