This Basic Science Review has been reviewed, accepted for publication, and approved by the author. It has not been copyedited, proofread, or typeset and is not a final version.

BASIC SCIENCE REVIEW

Paediatric Flatfeet: A 2020 Guide for Clinicians to Identify the ‘Boomerangs’

Angela Margaret Evans, PhD, FFPM RCPS(Glasg)*

*Discipline of Podiatry, School of Allied Health, Human Services and Sport, La Trobe University, Victoria, Australia; Marion Podiatry, Oaklands Park, South Australia; Walk for Life Clubfoot, Dhaka, Bangladesh(E-mail: angela.evans@latrobe.edu.au)

(Editor’s Note: Read the companion commentary at http://doi.org/10.7547/21-052)

The paediatric flatfoot has long occupied a place in the medical literature, with concerns about the significance of its appearance. At the end of the first decade of the 21st century, a paper in this journal provoked active debate about the paediatric flatfoot as part of development and proposed a considered titration of presenting cases in effort to justify treatment and appreciated the range and expected change in normal foot posture with growth. A decade later, the availability of normative paediatric foot posture data, and the prospective findings to confirm lessening flatfeet with age, encourage a structured and considered approach to this frequent primary care presentation. The pragmatic concept of the boomerang is built upon the research identifying the paediatric flatfeet likely to be symptomatic, thus requiring intervention, and filtering from those likely to remain asymptomatic. Differential diagnoses are advisedly considered, and gait remains the hallmark outcome. In this contemporary guide, an
eight step strategy has been developed to improve the approach to community paediatric flatfeet concerns. Further, the three 'boomerang' flatfeet factors delineating symptomatic from asymptomatic flatfeet, and applicable cut-off levels, are availed for practical reference and use. Given the recognised state of overdiagnoses and resulting unnecessary treatment that pervades the 21st century, it is timely for clear '20:20' vision for the presentation of the paediatric flatfoot.

More than a decade ago, a paper entitled, 'The flat-footed child - to treat or not to treat: what is the clinician to do?', presented a pragmatic and evidence-based clinical pathway for clinicians to use for paediatric flatfoot. Debate and argument followed this publication. This paper has more than 100 citations listed with Google Scholar, which indicates both impact and engagement with the topic since publication in 2008.

Now, in 2020, a novel concept of the 'boomerang' paediatric flatfoot, presents clinicians with greater clarity, and quells concerns about missing harmful paediatric foot problems, or, 'the one more likely to come back' (Figure 1).

Historically, a 'flatfoot' formed an exclusion criterion for military service, and this well-known fact has perpetuated an association between flatfeet and disability, with some 30 to 40% medical military discharges cited as being due to foot pain.
Ilfeld\textsuperscript{4} did further report, that many army recruits with foot pain had flat feet, suggesting that flat feet cause disability. This point was further reinforced by the observation that basic arch supports returned many flat-footed recruits to active service. However, it was also reported, that \textit{many soldiers with flat feet had no pain}; but this observation has rarely been cited. Hence, by omission, flatfeet became overly associated with pain. Despite this tenuous association, the very possibility of flatfeet causing pain and limiting independent mobility, has understandably concerned parents and clinicians when observing children with flatfeet. The notion of prevention is naturally attractive.

Undeniably, some flatfeet do induce morbidity, yet others function symptom-free, and most children’s flatfeet are painless. Thus, the dilemma, is knowing \textit{which feet are potentially problematic} to justify attention, and which feet can be averted from unnecessary treatment.

Young children are developmentally expected to have flatfeet, which reduce in ‘flatness’ with age\textsuperscript{6}, are flexible, functional, and pain-free. There are known systemic diagnoses, that need to be considered when growth, familial, and developmental ranges are not usual at any given age\textsuperscript{7,8}.

Greater clarity has been provided by recent studies, which have provided normative data for paediatric foot posture\textsuperscript{9,10}, refuted the previously cited\textsuperscript{11-13} relationship between increased BMI and flatfeet\textsuperscript{14,15}, and prospectively, shown that the majority of flatfeet do ‘straighten’ with age\textsuperscript{6}. 
Yet still, in 2020, paediatric flatfeet are a frequent clinical presentation to a range of medical and allied health clinicians\textsuperscript{16} due to parental (and doctor) concern and confusion regarding normality\textsuperscript{17}, with most treatment cited as unnecessary\textsuperscript{18}, and Level 1 evidence negating custom/bespoke foot orthoses in the absence of pain\textsuperscript{19,20}.

DISCUSSION

Signs of ‘Boomerang flatfeet’

Contemporary research has identified three factors which delineate symptomatic from asymptomatic flatfeet in children. Anatomically, the heel position and the height/congruence of the medial longitudinal arch, form the basis of most measures of foot posture\textsuperscript{21-24}, and with the addition of ankle range, propagate detection of the ‘boomerang’ paediatric flatfeet, as illustrated in Figures 2,3.

Valgus heel

Investigation of flatfeet in 97 children aged 5-18 years, using the Oxford Foot Model, classified feet as: asymptomatic neutral, asymptomatic mild flatfoot, asymptomatic flatfoot, or symptomatic flatfoot. Rearfoot eversion (average RCSP 10° eversion) and forefoot abduction (average 5° to 10° abduction) were significantly greater in symptomatic children\textsuperscript{25}.
This Basic Science Review has been reviewed, accepted for publication, and approved by the author. It has not been copyedited, proofread, or typeset and is not a final version.

**Talo-navicular joint (TNJ) coverage angle**

The differing alignment of foot segments, between symptomatic and asymptomatic children, was investigated retrospectively in 135 children by Moraleda et al. All participants (ave age 11 years) were recruited from three groups: asymptomatic flatfeet (n=45); symptomatic flatfeet with conservative treatment (n=45); and symptomatic flatfeet with surgical treatment (n=45). Radiographs of all feet were analysed and compared across groups, with differences between asymptomatic and symptomatic flatfeet were found in measures of talonavicular coverage [large effect size (0.59)] and lateral calcaneo-fifth metatarsal angle [small effect size (0.10)]. There was $10^\circ$ difference in TNJ coverage angles between asymptomatic (average 25$^\circ$) and symptomatic flatfeet (>35$^\circ$)\textsuperscript{26}.

These findings were replicated by Yan et al, in 100 children, aged 7-14 years (50 symptomatic, 50 asymptomatic flatfeet), where the lateral displacement of the navicular, measured as talonavicular coverage angle, related to symptoms (ave 25$^\circ$ asymptomatic, ave 38$^\circ$ symptomatic) \textsuperscript{27}.

**Ankle dorsiflexion range**

Kim et al, investigated the gait of 26 symptomatic children with flatfeet (age 7-13 years), and made comparison with a healthy control group (n=50).
The children with symptomatic flatfeet, most also limped, had average ankle dorsiflexion (knee extended) approximating 5.6° (10° in the controls), 30% ankle moment inefficiency, and 45% power inefficiency during gait, compared to the healthy controls. Further, gait showed that symptomatic flatfoot had increased rearfoot valgus, and a shortened lever arm for ankle dorsiflexion, both potentiating increased forefoot abduction (increased TNJ angle), midfoot break, and hence, kinetic disadvantage.²⁸

Identifying the problematic paediatric flatfoot

If sensible detection of the ‘boomerang’ flatfoot were adopted, identified children could be triaged for further assessment and treatment, and the ‘non-boomerang’ cases reassured accordingly. Given that overdiagnosis and overtreatment pervade healthcare in the 21st century,²⁹⁻³¹, it is highly relevant to avert unnecessary attention from paediatric flatfeet, by accurate diagnoses. Screening programs for paediatric (flat)feet have been aligned with WHO principles, and shown to be unjustified at a community health level.³²

The issue of unnecessary treatment of paediatric flatfeet has been previously reported. Pfeiffer et al.¹⁸ investigated 835 children aged three to six years and reported flatfoot in 44%. This study further reported that <1% cases were pathological, and yet 10% wore foot orthoses; hence, 90% of treatment was deemed unnecessary. Further, this study found that children’s flatfeet reduced with age, from 54% at 3 years of age, to 24% at 6 years of age.
In community medicine, the foot has been reported as the most common paediatric musculoskeletal problem in general practice \(^{16}\), yet normal feet found to account for 39.2\% of the specialist referrals for paediatric flatfoot concerns \(^{17}\). Concern about normal musculoskeletal variation is a continuing problem, with a recent evaluation of 2321 children referred to a paediatric orthopaedic specialty clinic, finding that one-third of children were normal for age, including 40\% with developmentally normal flatfeet \(^{33}\).

**How can we better manage paediatric flatfeet concerns in the community?**

Availing parents access to an interpretable version of the norms of foot growth and development, could enable fundamental *triage-at-home*, and avert persistent and unwarranted concerns about children’s flatfeet, especially in the first decade of life (see Further Resources).

The 3QQ (3 quick questions)\(^{34}\) translates assessment to assist both parents and clinicians to triage the most common paediatric lower limb presentations in primary care, viz. intoeing gait, genu varum/valgum, and flatfeet. As a coarse filter the 3QQ is helpful, however, there remains need for a considered and evidence-based approach to the paediatric flatfoot that is not painful, and yet *appears flatter than normal foot for age*, concerning and parents and clinicians alike \(^{35}\) (Figure 3).
Consulting the Foot Posture Index (FPI) normative data \(^\text{10}\) enables clinicians to benchmark the child concerned against same age values, mean (SD). Normative data shows that foot posture is variable across childhood with the mean FPI = 4 ± 3, and range -4 to +12. The FPI normative data has been translated for the clinical setting as a Ready Reckoner, providing mean FPI scores (±1SD, ±2SD), for each year of age (see Further Resources).

Even more compelling, is the recent prospective study, clearly demonstrating less paediatric flatfoot with increasing age, from three-year follow up data. The all-age mean percentage change in foot posture category showed an increase in supinated and especially in neutral feet (+0.7 supinated, +3.5 neutral), with concurrent reduction in pronated and highly pronated feet (-2.2 pronated, -2.0 highly pronated) as children aged three years \(^\text{6}\).

The paediatric flatfoot proforma (p-FFP) \(^\text{35}\) was developed to direct management for flatfoot cases, where FPI > +6 \(^\text{36}\). This tool filters cases on the basis of age and symptoms, with focus on differential diagnoses for children whose feet are flatter than expected, but not painful. The p-FFP takes a pragmatic approach to intervention, directing clinicians to monitor and use simple inexpensive interventions (structured footwear, generic foot orthoses, stretching and strengthening exercises) for asymptomatic children aged 8 to 10 years and older, whose feet appear flatter than is age-expected.

Both the normative data \(^\text{10}\) and the p-FFP\(^\text{8}\) rely on FPI scores which are not readily available for parents and many non-podiatric clinicians. Making normative data more accessible
This Basic Science Review has been reviewed, accepted for publication, and approved by the author. It has not been copyedited, proofread, or typeset and is not a final version.

for parents, and more clinicians alike might be facilitated by the use of RCSP, recently cited to correlate well with FPI. In a study of 208 participating children aged 8 to 13 years the FPI and RCSP were found to correlate r=0.71, and further, flatfoot was identified similarly, viz., in 26%, FPI and 23%, RCSP (left foot) \(^{37}\). The RCSP draws on the long-known involvement of the heel position (in addition to the medial arch) as an indicator of a flatfoot \(^{38,39}\). There may be potential to use the RCSP as a simple proxy indicator for FPI, which could avail easier access to the FPI normative data for parents, and a range of clinicians. This is a current inquiry.

In addition to the three signs of ‘boomerang’ flatfeet, overarching guidance directs that alert be given to children who present with: foot pain, left-right foot asymmetry, age over 10 years, limps, and is generally unwell, or refuses to weight-bear \(^{34}\).

**Wider considerations of the child**

The locus of controversy surrounding paediatric flatfeet and treatment, has intensified focus on flatfeet in older children (ie 8 to 12 years), who present without pain. The *camps* continue to exhibit duality:

- treat to prevent future problems \(^{40}\), versus,
- there is no evidence for custom/bespoke foot orthoses in the absence of pain, [treat according to gait, viz. footwear, strengthening, stretching, prefabricated foot orthoses, and re-check wider diagnoses \(^{35,41,42}\).}
This Basic Science Review has been reviewed, accepted for publication, and approved by the author. It has not been copyedited, proofread, or typeset and is not a final version.

Where some of the confusion, and resulting controversy seems to stem from, is the need to more broadly consider the child who presents with unexpectedly flat feet, and attempt to elucidate the factors associated with flatter feet at an older age. This juncture beckons clinicians to reconsider diagnoses, and check for potentiating factors, viz. joint hypermobility (connective tissue laxity and/or hypotonia – benign or syndromic eg Marfan’s, Ehlers Danlos syndrome, Trisomy 21, Osteogenesis Imperfecta)\textsuperscript{35}, deference to family history, delays in early development, foot strength and physical activity. Such an approach, will likely clarify wider diagnoses, and explain the less usual flatfoot presentations.

A further issue for diagnostic confusion, is the blurred relationship between children’s body mass and flat feet. Again, two camps have arisen, with one supporting a relationship between heavier children and flatter feet, and one not. Intuitively, the notion of heavier children having flattened feet is appealing, and a repeated conclusion of many studies\textsuperscript{11–13}. However, closer examination of the research sees that the origin of this divide is based upon differing methodology. The studies using footprint-based measures have supported relationship between heavier children and flat feet, whereas, more recent studies utilizing the FPI, refute this relationship\textsuperscript{14,15}.

Footprints, are commonly used as a basis of foot assessment, and surmise foot structure based on footprint area (flatter feet produce footprints with greater area). By contrast, the FPI, and the resting calcaneal heel position (RCSP), rate foot position. Hence, the different
conclusions about the relationship between increased body mass and flatfeet, has largely arisen from different methodologies, as recent comparison of measure types (footprints and FPI) from same subjects, has shown \(^{43}\). In essence, heavier children may have been skewed as having flatter (‘fatter’) feet, due to greater weight-bearing spread of foot adipose \(^{36}\).

An emerging theme for research, is the correlation between diminished foot strength and paediatric flatfoot. Children with flatfeet have been shown to have weaker toe grip strength than those with a normal arch \(^{44}\). Thus, due consideration may be afforded to increased BMI as a proxy for weaker feet, which are then flatter (due to ‘fatter’ footprints). This distinction is important when planning primary care, as nutritional support and physical activity need priority, given the health risks of paediatric obesity.

If flatfeet do not hurt, do they matter?

Functionally, gait observation is the most important aspect of assessment, and complements a thorough clinical history. Every paediatric flatfoot assessment should include clinical evaluation of gait, and every gait assessment should consider the effects of footwear. Footwear type and construction varies, hence different footwear can alter gait differently, and in some instances can be the underlying problem. The basic biomechanical functions of the foot enable adaption with weight bearing (pronation), stabilising for body mass carriage and heel lift (supination) to propel body mass forward on a stable forefoot, into swing phase, and the next step taken.
Proximal factors, eg leg ab/adduction, will alter gait patterns, and normal range varies considerably, eg gait angle range -5 to +15 across the population. Use of a validated gait assessment is applicable for school aged children as a quick screening examination to detect problems in the musculoskeletal system – gait, arms, legs, spine (GALS). The paediatrics GALS (p-GALS) begins with questions about pain and stiffness, ability to dress, ability to manage stairs, and then considers both appearance (swelling, deformity, abnormal posture), and movement (restricted, painful).

It is also relevant for clinicians to appreciate the angle of gait progression, as foot motion in the transverse plane has been demonstrably associated with symptomatic paediatric flatfeet, with symptomatic flatfeet having significantly increased forefoot abduction throughout gait, as compared to children with asymptomatic feet.

The evidence for intervention for paediatric flatfeet

The best available evidence for conservative interventions for paediatric flatfeet was been analysed as a Cochrane Library systematic review in 2010, and updated in 2021. The review from 2010 concluded, that in the absence of pain, the use of expensive, custom or bespoke foot orthoses for healthy children with flexible flatfeet had no supporting evidence. Clinical judgement needs to incorporate best available evidence for patient care, as directed by
thorough assessment, based on sound history, gait evaluation (Figure 3), and individual children’s physiology, social circumstances and general health needs.

Do we worry too much about children’s flatfeet?

It appears so, and may be traced back to the misinterpreted findings derived from 20th century military recruit studies. No clinician or parent wants to neglect any condition that will cause a child harm, thus the temptation to treat, ‘just in case’, may be well-intentioned, but overlooking the ‘harm’s of unnecessary treatment – the least being financial cost, for no benefit.

The idea that, ‘it is better to do something than nothing’, seems assiduous. However, the reality of ‘the harms of too much medicine’ must be appreciated and continually acknowledged in 21st century healthcare. Consumer education and empowerment to this effect, are increasingly available thorough sites such as ‘Choosing Wisely Australia’, which aims to identify common interventions, that are shown to be baseless and wasteful.

CONCLUSIONS

‘Twenty-twenty’ vision for clinicians and parents in 2020 and beyond, regarding the significance of flatfeet in children, requires best-available evidence to be structured for an accessible use.
The norms of paediatric foot development are now ‘bench-marked’, with reduction of flatfoot expected as children grow. Simple triage sifts most likely problems from normal range variations, and three specific foot attributes enable clinicians to identify the ‘Boomerangs’ – the children whose feet will probably cause future pain.

Easy, and validated gait assessment, contextualises the effects of foot posture. In the absence of pain, yet inefficient gait, both wider diagnoses and application of fundamental interventions (viz. footwear, strengthening, low-cost prefabricated foot orthoses) need to be considered.

Childhood obesity, physical inactivity, and resulting deficits to child health and quality of life, need to be appreciated by every podiatrist who consults in the paediatric healthcare setting.

Financial Disclosure: None reported.

Conflict of Interest: None reported.

REFERENCES

This Basic Science Review has been reviewed, accepted for publication, and approved by the author. It has not been copyedited, proofread, or typeset and is not a final version.


7. Evans, A. M. The Flat-Footed Child—To Treat or Not to Treat. dx.doi.org 98, 386–393 (2014).


This Basic Science Review has been reviewed, accepted for publication, and approved by the author. It has not been copyedited, proofread, or typeset and is not a final version.


This Basic Science Review has been reviewed, accepted for publication, and approved by the author. It has not been copyedited, proofread, or typeset and is not a final version.


This Basic Science Review has been reviewed, accepted for publication, and approved by the author. It has not been copyedited, proofread, or typeset and is not a final version.


This Basic Science Review has been reviewed, accepted for publication, and approved by the author. It has not been copyedited, proofread, or typeset and is not a final version.


This Basic Science Review has been reviewed, accepted for publication, and approved by the author. It has not been copyedited, proofread, or typeset and is not a final version.


Additional References


This Basic Science Review has been reviewed, accepted for publication, and approved by the author. It has not been copyedited, proofread, or typeset and is not a final version.

**Figure 1** - Gait observation of the boomerang paediatric flatfoot

The “3 A’s” for gait concerns, viz. Abducted, Apropulsive, and Awkward. Endurance and balance may also be reduced in children with boomerang flatfeet, as compared with same-age peers with non-boomerang feet. Full consideration should be given to wider diagnoses.

Clinically, the ‘boomerang’ represents:

1. medial prominence of the talo-navicular joint, and convexity of the medial border.
2. the proximal boomerang arm represents the valgus heel
3. the distal boomerang arm represents to abducted forefoot

Reduced ankle joint dorsiflexion is concurrent.
Figure 2 – Boomerang paediatric flatfeet

Checking for ‘boomerang’ flatfeet involves the three factors shown to delineate symptomatic from asymptomatic flatfeet in children, and applicable cut-off levels.
Figure 3 – The 20:20 Vision for Paediatric flatfeet

Eight steps (the “Eight P’s strategy”) to improve the approach to community paediatric flatfeet concerns.

1. Parents: can use the plain language 3QQ to triage pain, symmetry, age based flatfeet

2. Population: FPI normative data is available for clinicians

3. Pragmatism: when the FPI is > +6, clinicians can use the p-FFP which directs diagnosis and treatment according to age and symptoms

4. Paediatric GALS: validated gait assessment and screening is availed for clinicians

5. Practical: gait need to be assessed with and without regular footwear

6. Physical, Physiologic: consideration for BMI, and physical activity for age are important for a child’s overall health

7. Probabilities: most paediatric flatfeet are not pathological, but consideration must be given to more serious diagnoses if feet are painful, asymmetrical, rigid, or if the child is unwell, or limps.

8. Plans: any intervention requires applicable outcome measures, and review of foot posture and gait according to growth and age need valid baseline assessment for comparisons over time.
This Basic Science Review has been reviewed, accepted for publication, and approved by the author. It has not been copyedited, proofread, or typeset and is not a final version.

Parents
Population
Pragmatism
Paediatric GALS
Practical
Physical, Physiological
Probabilities
Plans

3 Quick Questions: 3QQ
Normative foot posture Ready Reckoner: FPI
FPI >6, Paediatric flatfoot, p-FFP
Gait: p-GALS
Gait: footwear effects
Child – Physical Activity, BMI
Diagnoses
Treat Review

20:20 Vision
Paediatric
Flatfoot