DEVELOPMENT OF A COMBINED BENDING STIFFNESS INDEX FOR CYCLING AND OUTDOOR FOOTWEAR

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Introduction

Footwear bending stiffness represents one of the most important functional properties in athletic footwear (Stefanyshyn and Wannop, 2016, Kleindienst et al. 2004) covering all three main aspects of functional footwear: injury prevention, comfort and performance. During walking the shoe should provide an appropriate dorsiflexion (in following DF) around the MTP-joints to ensure a smooth ride. Contrary, cycling shoes should be stiff to allow a direct power transmission from the foot to the pedal. However, there are specialty shoes, such as for cycle touring, which should offer both a smooth ride during walking and adequate power transmission during cycling. The aim of this study was to develop a combined bending stiffness index to evaluated cycling and outdoor footwear according to activity and its functional requirements based on longitudinal bending stiffness.

Material & Method

To investigate the longitudinal bending stiffness a mechanical testing device (TUM TrakTester) was used (Grund & Senner, 2010; **Fig. 1**). The device measures forefoot and midfoot flexibility regarding both dorsal flexion and plantar flexion (in following PF) movement. The longitudinal bending stiffness of the whole shoe was determined containing outsole, midsole, insole and upper. Different loading conditions were applied and the resultant bending angle was measured (**Fig. 2**). Ten outdoor shoes and 8 cycling shoes were tested differing in functional requirements based on their field of use.

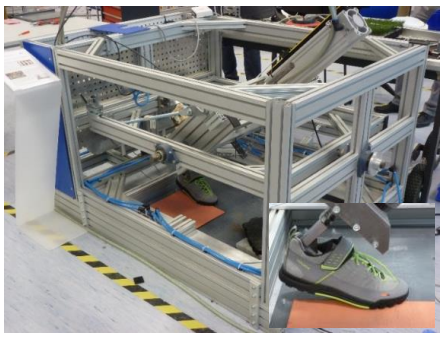


Fig. 1: TUM TrakTester (modified to measure longitudinal bending stiffness in athletic footwear)

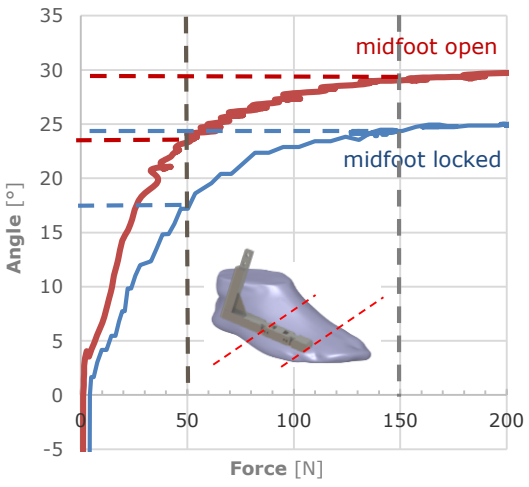


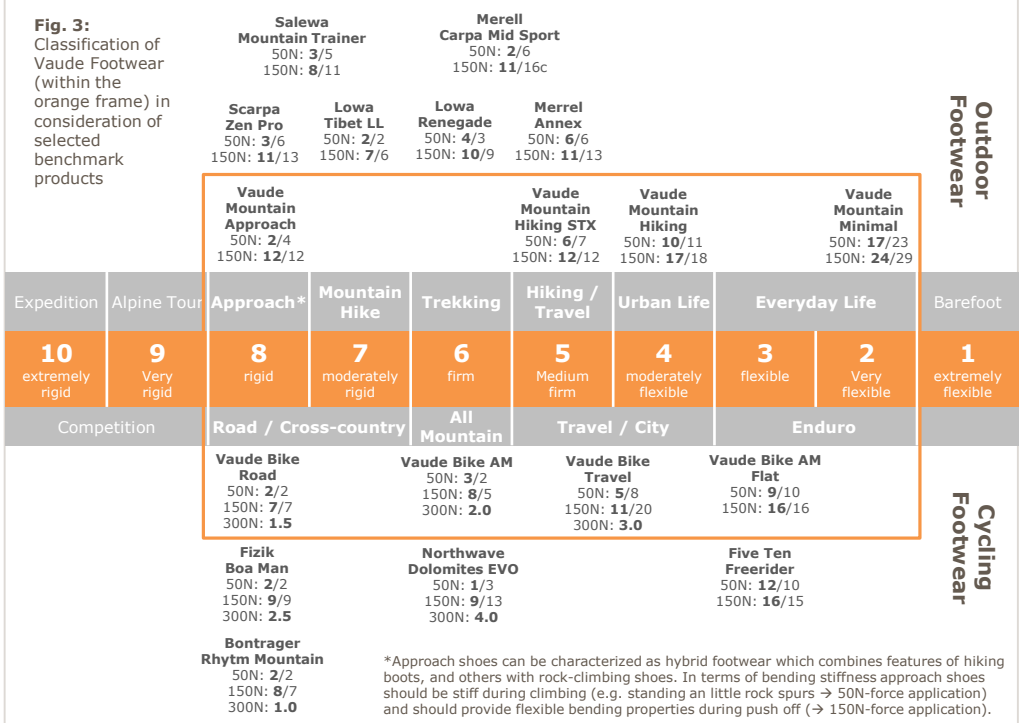
Fig. 2: Angle-Force-Diagram displaying the measured parameters for dorsiflexion bending (Vaude Mountain Minimal) and image of metal-skeleton in foot prosthesis with marked flex axes (MTP and Chorpart's Joint)

- 2 Flex axes
  - **Total-Bending-Stiffness** → MTP-Joint: open & Chorpart's Joint: open (midfoot)
  - **forefoot-Bending-Stiffness** → MTP-Joint: open & Chorpart's Joint: locked (midfoot)
- 2 Flex directions
  - **Dorsiflexion:** Flexibility important for a smooth ride during gait → Comfort criteria
  - **Plantarflexion:** → Stiffness important for power transmission during pedalling cycle → performance criteria
- 3 Forces of application
  - **50 N** → Bending: dorsal/plantar at moderate force application
  - **150 N** → Bending: dorsal/plantar at high force application
  - **300 N** → Bending: plantar → cycling shoes with click pedals only

Results

For outdoor footwear, the stiffness bending index consists of 4 values (fore-/midfoot at 50/150N; **Fig. 2**) measured during DF. For cycling shoes one additional value during PF is considered. Depending on the field of use the tested footwear exhibit different bending stiffness properties. Within outdoor footwear, shoes belonging to the category "Approach" indicate much stiffer bending characteristics compared to "Urban Life" (**Fig. 3**). In cycling, the tested shoes of the "Cross Country"-category exhibit clearly stiffer PF bending characteristics compared to "Cycle Touring" (Vaude: Travel/City-category). Besides, tested footwear for "Cycle Touring" show a similar DF forefoot flexibility like "Hiking".

Fig. 3: Classification of Vaude Footwear (within the orange frame) in consideration of selected benchmark products



Discussion, Conclusion & Application

Data recorded with the TrakTester allows the development of a combined bending stiffness index for outdoor and cycling footwear. The informative value of the mechanical testing is confirmed by several subjective test reports published in consumer magazines (Bayer, 2017). However, a comparison with other studies is not possible since the method to determine the bending stiffness vary strongly (Stefanyshyn and Wannop, 2016, Krumm et al., 2013).

Only one study (Jarboe and Quesada, 2003) could be found, which analyzed the PF as well as DF bending stiffness. Within two road cycling shoes differed only in outsole material (carbon-fibre-composite vs. plastic). The "carbon"-shoe revealed much stiffer bending properties regarding both DF and PF. Moreover, during cycling the "carbon"-shoe caused much higher average plantar peak pressure compared to the "plastic"-shoe" which can provoke metatarsalgia or ischemia. The authors recommend for those users who are more comfort oriented (and not just performance oriented) to use less stiffer footwear.

The results of the tested bike footwear belonging to the "Travel & City" and "Enduro" category (according to the bending stiffness index 3, 4 and 5) exhibit sufficient PF stiffness for power transmission during cycling and offer flexible forefoot dorsiflexion properties to ensure a smooth ride during walking (**Fig. 4**). Hence, this kind of footwear is perfectly suitable for activities such as "bike & hike", "bike to work" or "bicycle touring".

Based on the index, the longitudinal bending characteristics of a shoe or a new technology incorporated in a prototype can be evaluated and improved according to the field of use and its requirements.

Within Vaude the combined bending stiffness is called "V-FLOW-Index" (**Fig. 4**). The V-Flow-Index should help retailers at the Point of Sales and may support the athlete to find the right shoe for its preferred activity.

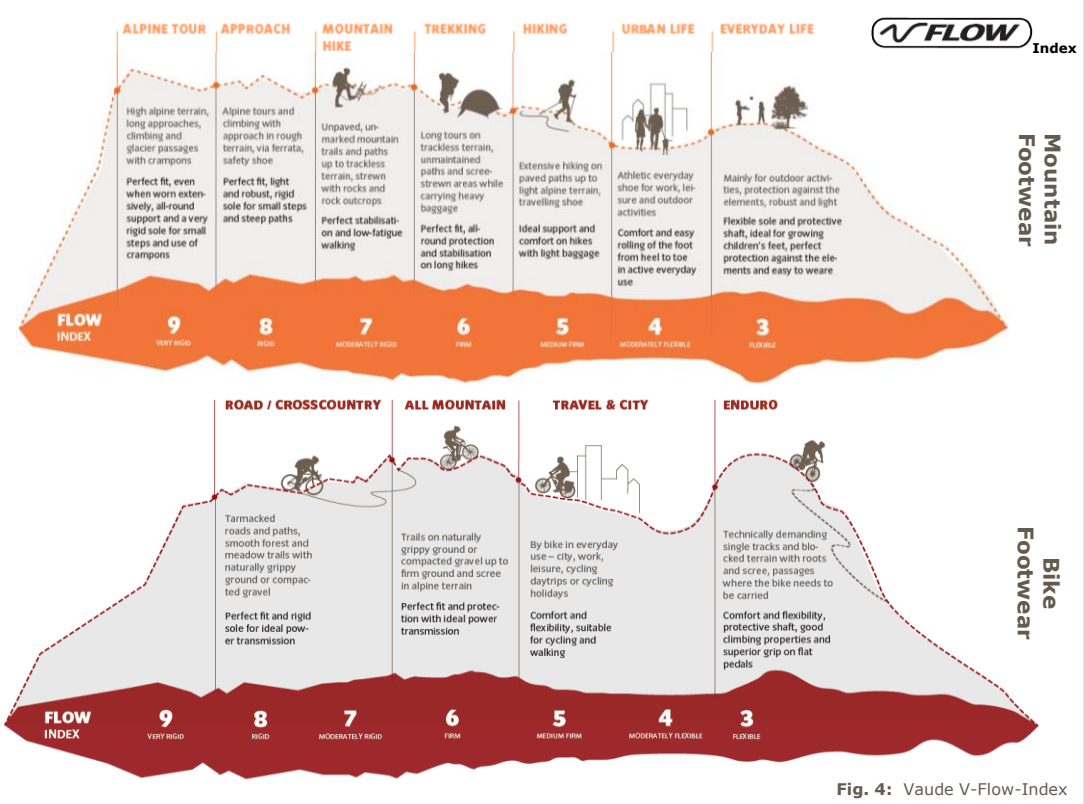


Fig. 4: Vaude V-Flow-Index

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