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Quantification of the material properties of the heel pad is important for computer-aided analysis of patient-specific therapeutic footwear designs and foot pathologies. However, parameter identification of the hyper-elastic material properties of the plantar soft tissues usually requires an inverse finite element (FE) analysis because of the lack of practical contact model of the indentation test. In the present study, we propose a method to identify the material parameters of the heel pad based on an analytical contact model of a spherical indentation test. Force–displacement curves of the heel pads were obtained from an indentation experiment on 5 healthy adult participants. The experimental data were fit to the analytical stress–strain solution of the spherical indentation test to estimate the parameters. The present spherical indentation approach successfully predicts the non-linear material properties of the heel pad without conducting inverse finite element analysis. The stiffness of the heel pad quantified in the present study was found to be slightly lower than those identified in the previous studies. The proposed framework to identify the hyper-elastic material parameters may facilitate development of subject-specific FE modelling of the foot for possible clinical and ergonomic applications.

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Time change in strain distribution on the lateral and plantar surfaces of the foot during walking

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Detailed understanding of the strain distribution of the human foot surface is crucial for ergonomics design of shoe and clinical treatment of the pathological foot. However, it has not been fully investigated due to difficulty of measurement. In this study, we aimed to clarify the three-dimensional (3D) strain distribution of the human foot during bipedal walking by means of digital image correlation (DIC) method, an optical method to measure 3D deformation of an object surface by using the stereo-triangulation and the image correlation of speckle pattern on the object surface. We filmed the lateral and plantar surface of the right foot during the stance phase of the ten adult males using four synchronized high speed cameras. A glass plate and a mirror was buried in the middle of walkway for the plantar surface measurement. The right foot was sprayed with aqueous black ink to draw the speckle pattern and we calculated time change in the 3D foot shape and skin strain distribution during stance phase. The accuracy of the shape and deformation measurement was confirmed to be about 0.1 mm, sufficiently accurate for quantitative description of the foot deformation. Our results demonstrated that the lateral surface around the cuboid was stretched in the early and late stance phase. In the plantar surface, around the ball of the foot was stretched throughout the stance phase. The present framework may serve as an effective tool for understanding of the pathogenic mechanism and design of the orthosis for foot disorders such as diabetic foot.

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Relationship of comfort perception and running biomechanics in running shoes with varying midsole hardness

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Background: Running shoe comfort perception has been discussed over the past few decades, but the relationship between comfort and biomechanical variables have not well established.

Aims: The aim was to establish the relationship between comfort and biomechanical parameters in running shoes with varying midsole hardness.

Methods: Nine healthy young male runners ran a straight ahead run with controlled speed at 3 m/s when wearing each of the shoe hardness conditions (20, 30, 40, 50, 60, 70 & 80 Asker C). Three-dimensional kinetic and kinematic data were captured and 100 mm Visual Analog Scale on comfort perception was rated after each shoe condition. Five successful trials were collected for each shoe. Person bivariate correlation tests and multiple non-linear regressions were performed to determine the regression equation between the comfort and various biomechanical parameters (GRF impacts, joints kinematic and kinetics).

Results: The comfort perception were highly correlated with three biomechanics parameters including maximum vertical force of the ankle joint (VA), the time to the first GRF peak (TFF) and maximum knee flexion angle (KFA). The overall regression model is expressed below:

$$\begin{aligned}\mathrm{Y(comfort)} &= -17.081 + 0.008(\mathrm{TFF}) - 3.161(VA) - 0.004(\mathrm{KFA})2 \\ &\quad + 0.435(\mathrm{KFA})R2 \\ &= 0.912\end{aligned}$$

Conclusions: Subjective comfort perception increased in response to time to the first GRF peak while decreased in response to the maximum vertical force of the ankle joint. Comfort perception increased when KFA at (45–50°) and decreased at (50–55°). This relationship may imply that increased time to the first GRF peak in footwear and controlled knee flexion angle by training would influence footwear perception rating in running.

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A stakeholder informed, low-cost, personalised 3D-printed insole for diabetic foot ulcer prevention

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Background: Diabetic Foot Ulcer (DFU) incidence will rise in line with the increasing global prevalence of diabetes. Healthcare providers must develop effective interventions that address the needs of patients and clinicians if DFUs are to be prevented.

Aim: Engage with stakeholders (patients and clinicians) to inform the development and evaluation criteria of a novel low-cost 3D-printed insole to reduce DFU risk in patients with neuropathy.

Method: Data from the transcripts of 15 semi-structured patient interviews and the views of 7 podiatrists were used to develop a consensus statement of insole design specifications.

A prototype insole was developed and evaluated against these specifications. Clinical effectiveness was established by comparing reduction in peak plantar pressures and patient perceived comfort of 4 people with diabetic neuropathy whist wearing 1) no insole 2) standard custom insole and 3) 3D-printed insole conditions. The F-scan in-shoe pressure measurement system was used to collect kinetic data. Insoles were presented in a random order with participants blinded to the condition.

Results: The 3D-printed insole fulfilled most of the design specifications including being lightweight, easy to clean and walk in. It was more effective at reducing forefoot plantar loads when compared to the standard insole condition, reducing mean peak plantar pressure by 31%, a 4% greater reduction over the standard insole condition.

Conclusion: This study provided valuable pilot data for the efficacy, acceptability and future direction of this intervention. The impact of stakeholder involvement on insole design, adherence and ulceration rate need to be evaluated through a clinical trial.

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Spatio-temporal and kinematic analysis of ankle arthroplasty versus arthrodesis

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Background: End-stage ankle arthritis surgical treatments include arthroplasty and arthrodesis. Comparison studies are sparse [Piriou 2008; Saltzman 2009], however, functional differences must be quantified to aid surgeons in selecting the best treatment for individual patients.

Aim: The aim of this study is to determine if arthroplasty improves spatio-temporal parameters and ankle kinematics compared to arthrodesis.

Methods: Preoperative and postoperative gait analyses were performed on arthroplasty ($n = 18$) and arthrodesis ($n = 10$) subjects. A multi-segment foot model was used to calculate spatio-temporal parameters and ankle kinematics with a 12-camera Vicon MX system sampling at 120 Hz. Two to five force plates collected ground reaction forces sampling at 1200 Hz. Subjects walked barefoot at a self-selected speed for five trials. A repeated measure ANOVA detected significance between and within groups, followed by the Benjamini-Hochberg procedure if significance was detected.

Results: Preliminary statistics indicate both treatments significantly increased walking speed, from an average of 0.97 m/s to 1.12 m/s for arthroplasty and 1.09 m/s to 1.17 m/s for arthrodesis ($p < 0.005$). Cadence significantly increased following arthroplasty ($p < 0.005$). To understand gait symmetry, step length ratio was calculated (affected limb/unaffected limb). Step length symmetry significantly increased following arthrodesis ($p < 0.05$) and compared to arthroplasty ($p < 0.02$). Finally, ankle joint sagittal range of motion decreased after arthrodesis ($p < 0.005$) and increased after arthroplasty ($p < 0.005$).

Summary/Conclusions: Initial findings give insight into the strengths and weaknesses of both treatment options for end-stage ankle arthritis.

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Talonavicular, not the Subtalar, is the dominant intrinsic foot joint

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Background: Spawned by the mid-20th Century landmark studies of Inman and colleagues, efforts to functionally appreciate and clinically assess the subtalar joint have captured the attention of movement scientists and clinicians alike. Linking foot frontal plane and leg transverse plane motion, the mitered-hinge concept;, is assumed to originate from the subtalar joint, and from this understanding, mid to forefoot motion of the mid-tarsal joints is described. Recent investigations suggest that the talonavicular joint may be the source of many of these presumed subtalar functions. This suggests that talonavicular, and not subtalar, function may be the key to understanding intrinsic foot joint activities.

Aim: To determine the relative contribution of the subtalar and talonavicular joints to midfoot function.

Methods: Inversion-eversion motion data were based on bone-pin clusters inserted into cadaveric specimens. After first observations, the subtalar or the talonavicular joint was rendered immobile. Motion patterns from these conditions were compared to identify the relevance of the subtalar versus talonavicular joint to overall midfoot motion patterns.

Results: In the unfixed condition, talonavicular joint motion typically exceeded that of the subtalar or calcaneocuboid joint. Talonavicular joint restriction had a large effect on midfoot mobility, effectively locking out most intrinsic foot motions. Restriction of the subtalar joint had a subtractive effect on talonavicular joint motions, but did not eliminate the motion of any other joint.

Conclusion: The talonavicular joint - not the oft-studied subtalar joint - is the dominant intrinsic joint of the foot.

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