All Work and No Play: does this make Jack a tall boy?

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Introduction

Football is renowned for being the most popular international team sport[1] and the attraction of a prosperous professional career is enticing for young enthusiasts. This has led to a greater number of increasingly younger individuals participating in organised training regimes that use repetitive exercises in order to develop specialist skills[2].

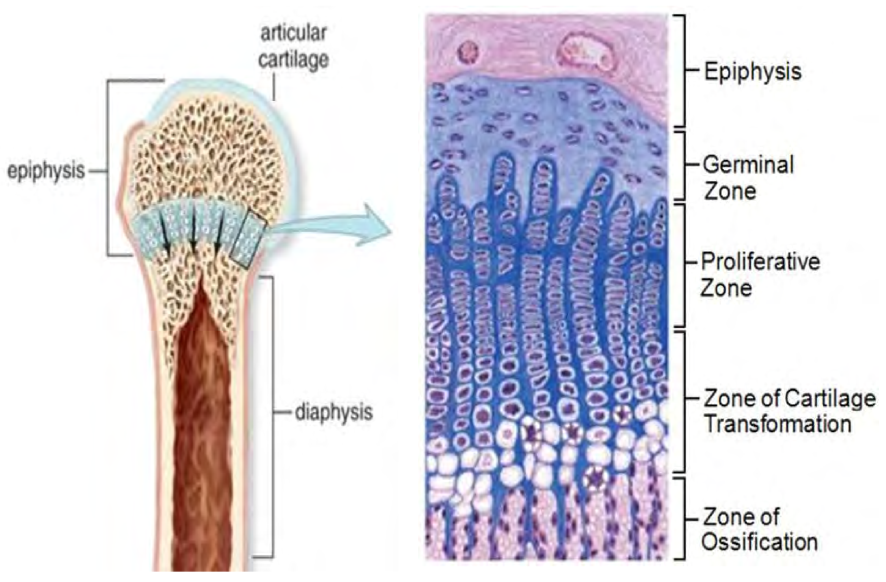

Figure 1 - The epiphyseal plate is the cartilaginous 'growing' area of long bone which consists of four conceptual zones (adapted from McGraw-Hill[6]).

While obesity and inactivity is a mounting problem for the general population[3], the increased intensity of complex skills practised by competitive young athletes is just as perturbing with respect to the unknown health risks associated with prolonged intensive exercise.

The lack of scientific guidelines to prevent overtraining[4] is partly due to the limited number of longitudinal studies which assess growing athletes over many years. The gap in the literature leads to a weakness in scientific understanding[5]; thus the potential to uniquely combine Motion Analysis (MA) and Magnetic Resonance Imaging (MRI) to assess the development of young athletes. This research may affect the design of future health support mechanisms to protect the vulnerable area of bone growth (the epiphyseal plate) as illustrated in **Figure 1**.

Aim

The aim of this research is to broaden scientific understanding with respect to the epiphyseal plate and subsequent development of long bones; in addition to exploring the influence exercise has on the biomechanics of gait and the future health and welfare of amateur and professional athletes.

Objectives

- Determine any potential health risks for the welfare of individuals by analysing MA three-dimensionally, in terms of kinetic and kinematic data, to determine otherwise hidden weaknesses that may arise due to intensive sports training.
- MRI could reveal potential micro-damage of the growth plate as a consequence of excessive exercise.
- If an individual's biomechanics are found to place additional detrimental stresses and strains across the lower limb joints, this research will enable their walking, running and exercise techniques to be altered accordingly.

Method and Materials

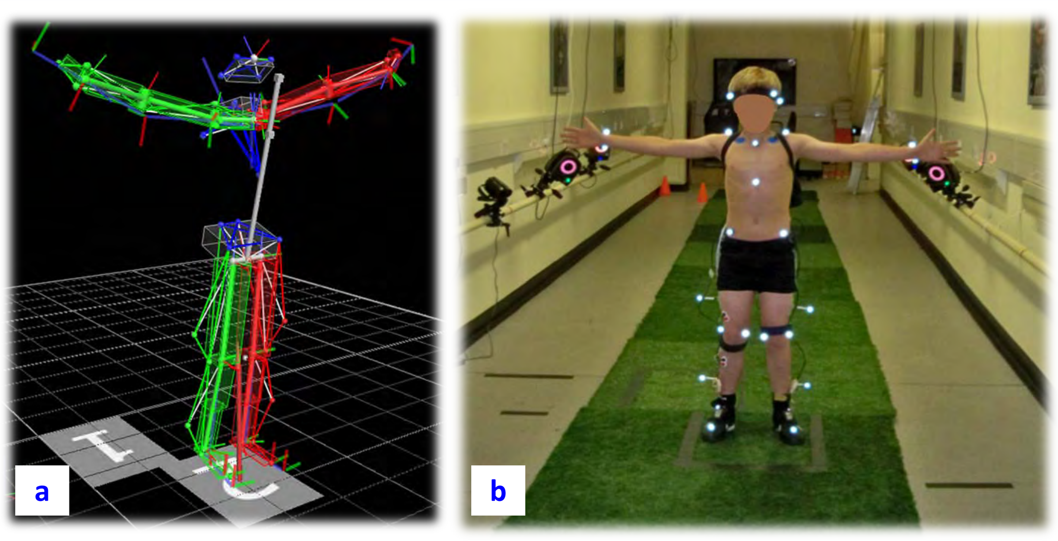

Figure 2 – Subject in Sports Laboratory.
2**(a)** 3-D reconstruction of a static trial in Vicon®.
2**(b)** Photograph depicting Full Body marker placement at anatomical sites.

Figure 3 – Pedar-x® box and examples of in-shoe pressure sensing insoles.

This study assessed 15 young male footballers aged between 12-14 years who attend Rangers Youth Academy. This active group were compared to an age-matched cohort of 15 non-trained school boys with a more sedentary lifestyle. Motion of the musculoskeletal system of individuals walking and running was captured using the Vicon® MX system with concealed AMTI® force plates in the Sports Laboratory, located in the Institute of Motion Analysis and Research (IMAR) and pictured in **Figure 2** which also presents an example of obtaining a static trial.

Pedar-x® was used to simultaneously measure in-shoe pressure and reveal the specific distribution of forces at key anatomical points of the foot. **Figure 3** is a photograph of the Pedar-x® box which was carried in a specially altered back pack.

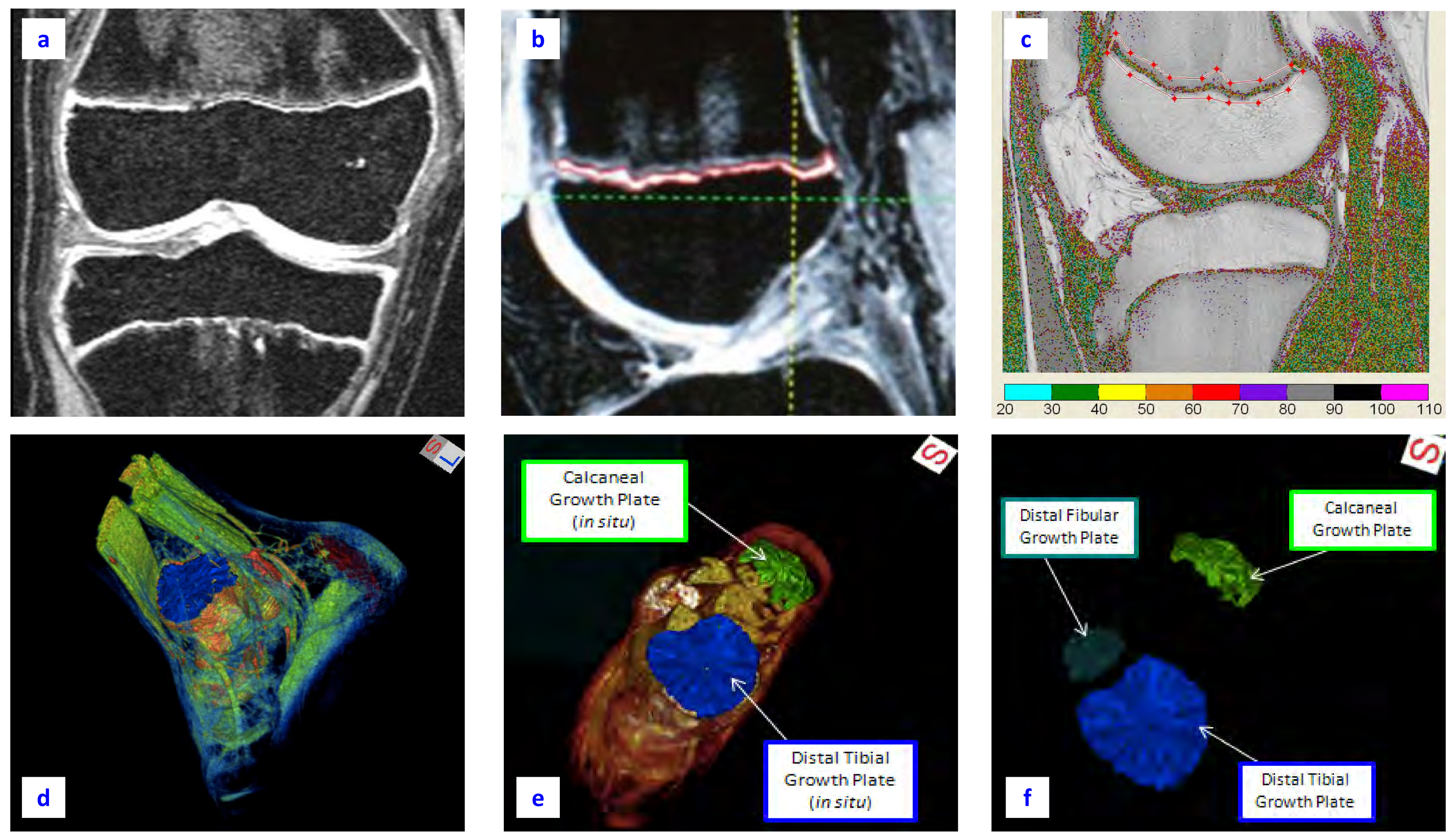

Figure 4 – **a)** Coronal view of DESS MRI of the dominant right knee. **b)** DESS image highlighting the 'livewire' tool which enables outlining of the growth plate as seen in red. **c)** T2 image after extensive algorithmic programming to compute and process T2 pixels. **d) to f)** 3-D reconstructions of growth plates of the ankle created using OsiriX® software.

The second phase of the research was carried out on the same day at the Clinical Research Centre (CRC) where MRI scans non-invasively generate images of the internal anatomical structures at the knee and ankle; thus enabling epiphyseal plate dimensions and volumes to be calculated and visualised in 3-D. Three different software programs were used (OsiriX®, Endpoint® and MATLAB®) to quantify the volume of each epiphyseal plate around the knee and foot and **Figure 4** depicts examples of the MRI software available.

Results

This research reveals that there is a significant difference in the kinematic and kinetic data when comparing the MA of individuals in the active and control groups. The influence that intensive sports training has on the biomechanical development is particularly evident in relation to the difference in running style; pairwise comparisons confirmed that the active group tend to adopt an efficient toe-running technique and this dramatically contrasts with the heel-strike running technique selected by the control group. One example to support this, is the maximum force (MF) graphs in **Figure 5** illustrate that the MF at the heel of active group when running was lower by 215N ($p<0.001$) and the MF at the toes of the active group was 21N greater for the 2nd toe ($p<0.001$).

The MRI findings did not find a statistically significant difference in the volume of the epiphyseal plates; however a complex trend in relation to the pattern of skeletal development was found in the active group which was not found in the control group.

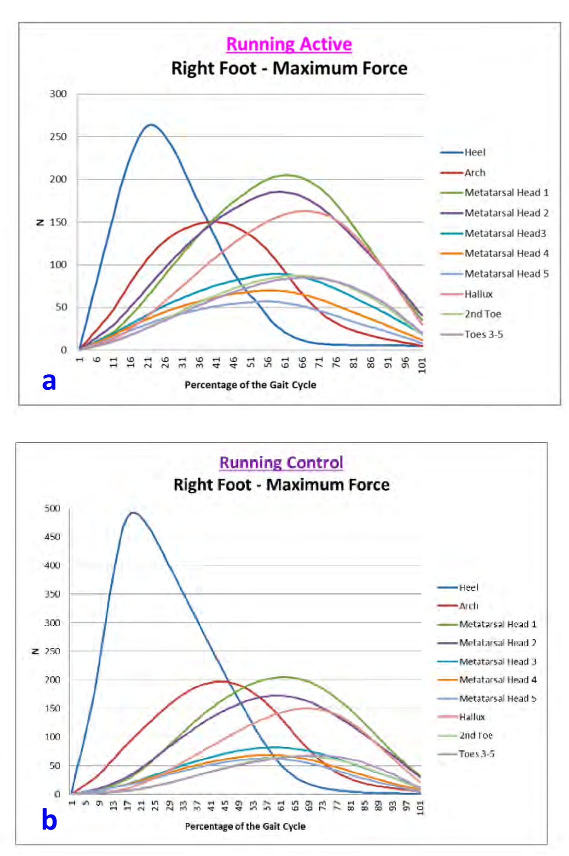

Figure 5 – Graphs illustrating Maximum Force of the right foot recorded by Pedar® while running.
(a) Active group.
(b) Control group.

Discussion

Ultimately this research provided greater insight as to the appropriate prescription of training for young athletes. If an individual's biomechanics are found to place detrimental stress and strain across the lower limb joints, or if MRI reveals otherwise hidden micro-damage to the epiphyseal plate, clinical analysis of the motion will enable beneficial intervention to assist with their running and exercise techniques. This research may also provide information on the levels of exercise required to induce positive changes in growth at skeletally vulnerable stages of development, therefore enabling us to prevent possible long-term health risks and give a better understanding of how bones adapt to our changing lifestyles.

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