The impact of high volume training on bone density in adolescent and young adult sports academy players and the effect of off-loading post injury.

£9,951 has been awarded to this project

Principal Aim of the study
The primary aim of this study is to measure the changes in the bone mineral density (BMD) of young people who regularly participate in high volume training programmes and have had their weight bearing ability compromised for a minimum of 4 weeks following an injury.

Primary Research question
What is the relationship can be identified between compromised mobility for a minimum period of 4 weeks following an injury and the bone mineral density of young males over a one year period, with particular focus on those who regularly participate in high volume exercise and training programs?

Secondary Research questions
- How does BMD differ in high intensity sport athletes compared to age, gender and race matched controls in adolescent and young adult males.
- What relationship, if any, will off-loading have on areal measurements of muscle and fat?
- Does the skeletal age of athletes match their chronological age and does this differ from their age matched non athletic controls?
- What effect does the type of injury sustained have on weight bearing ability and consequently BMD?

Outcomes
The primary outcome measure will be determining the length of time observed before BMD returns to 'normal' levels in the previously injured young athlete. The research will also examine the effect of high volume training on BMD and body composition as compared to age matched controls and will include obtaining blood samples to explore markers of bone turnover, hormonal profiles and to identify indicators of inflammation.

Comparison of skeletal age with chronological age will be undertaken using DXA and can be performed at the same time as the baseline DXA scans; assessing bone age will demonstrate whether there is a predisposition for more physically active individuals to achieve skeletal maturity earlier than their age matched controls.

Review of the literature and identification of current gap in knowledge
The number of children and adolescents who now participate in high intensity training for a variety of sports has risen, and specialisation in their chosen field begins at a relatively early
Participation in sport for some is no longer a solely recreational activity, but instead has become a viable career prospect for the dedicated and talented few. Football is the most popular sport worldwide with an estimated 265 million players in 2006\(^1\), and, following the publication of Howard Wilkinson’s ‘A charter for quality’ in 1997 has seen the number of youth players competing at a high level increase with the introduction of more academies all over the UK. The introduction of the Elite Player Performance Plan (EPPP) in 2011 by the Premier League, whilst ensuring a more rigorous regulation of coaching standards and facilities, has also allowed a greater physical burden to be placed on young athletes, which in turn may result in an increased susceptibility to injury.

It is widely appreciated that physical exercise during childhood and adolescence is an important factor in the promotion of good bone health and can have a positive effect on bone mineral density in the immature skeleton\(^2\). Exercise is known to stimulate osteogenesis; this in turn has been shown to result in an increase in the bone mineral content and peak bone mass of active individuals by around 10% to 20% when compared with their more sedentary counterparts\(^3\). The amount of peak bone mass achieved at the end of adolescence can go on to play a potentially significant role in the reduction of possible future fractures\(^4\). However, during the teenage years a mismatch can be seen between growth and strength. The increases in height that occur during the adolescent ‘growth spurt’ does not necessarily correlate with an increase in bone mass. Adolescents undergo periods of rapid bone growth that can result in an imbalance between muscular strength and bone strength. It is at this point that the immature skeleton may become susceptible to injury or even fracture\(^5, 6\). The age of young athletes predisposes them to certain injuries relative to inherent weaknesses in the growing skeleton. The majority of these injuries relate to sprains and strains; however physisal injuries, apophysitis and overuse injuries can also be found amongst this group\(^7\).

There have been studies examining the difference in bone density between athletes undertaking weight bearing exercise (football, running etc.) and those who also undertake high intensity training but which is not weight bearing, such as swimming\(^8, 9\).

There are several studies which have investigated specifically the bone density of adolescent female athletes relative to their choice of sport, menstrual function and BMI and the association of these factors with stress injury\(^10, 11, 12\). In addition, there is research on the effects of high volume training and the vitamin D levels seen in various groups of athletes\(^13, 14\) which has observed a surprising number of athletes exhibiting lower than expect levels of vitamin D. However, there seems to be little reported data as regards the long term effect of injury and offloading on the bone density of young athletes participating in high volume exercise. One study examined the changes in bone density following immobilisation in a cast in children aged 16 years and under. Their findings demonstrated a significant drop in BMD by the time of cast removal\(^15\). These researchers published further data with regard to long term observation of the BMD levels in a sample of 50 adolescents aged from 10 to 16ys. Their BMD was measured at 6 and 18 months following injury and the results demonstrated a significant change in BMD in between injured and non-injured limbs at 6 months, but little residual difference between injured participants and controls at more proximal sites such as
the neck of femur. However as expected, the participants demonstrated rapid bone turnover in comparison to adults, and by 18 months no significant difference in BMD was detected. In conclusion, the current research available on the effect of partial or complete offloading following injury, particularly with regard to long term changes, on the BMD of young athletes is significantly limited. A reduction in bone density is a proven risk factor for future fracture, additionally there is clear evidence that the skeletally immature athlete faces a significant risk of musculoskeletal trauma, either as a result of an acute event or due to an overuse injury. A reduction in BMD could present an added risk factor following a return to normal training levels. An understanding of the potential effect on the bone density of young athletes may allow the devising of appropriate rehabilitation programmes that will aid in the prevention of re-injury or stress fracture. This is an important factor in maintaining the health and fitness of young athletes and ensuring they can remain in their chosen sport.

Methodology

Study design
This will be an observationally based, longitudinal cohort study, it will look at changes to BMD over a period of 12 months and will take measurements of bone density at specific time points over the duration of the study. 83 participants will be recruited in total and will comprise 2 main groups; a control group of 60 which includes equal numbers of those who engage in regular high volume exercise training programs and those who do not. A second group of 23 participants will be recruited to explore the primary research question regarding the effect of offloading on BMD. All scanning and blood tests will take place at the University of Exeter, St Luke’s Campus. The participants recruited into the study will consist of male Caucasians in order to reduce any potential gender and ethnicity confounders, and will be aged between 16 and 21 years. It is well evidenced that black males have increased BMD when comparison is made with their non-black, age matched peers.

Control Participants
Those participants in the non-injured arm of the study will receive a DXA scan to include their lumbar spine, bilateral hips and knees and total body in order to provide baseline measures of bone density and areal measures of lean muscle and fat. These scans will be repeated at 6 months and then finally at 12 months. This number of scans and the anticipated time frame will allow the demonstration of any changes in BMD levels as well as body composition.
A single DXA scan of the participant’s non-dominant hand will be performed at the initial appointment in order to compare their bone age with their chronological age using the Gruelich and Pyle method.

Injured Participants
Academy staff at the sites who have agreed to participate in the research will be asked to contact the research team if a player sustains a significant injury resulting in immediate non weight bearing, and either attendance at an emergency department or similar, or urgent referral by a health care professional for diagnostic imaging. Academy staff will be asked to
notify the research team of any injury as soon as practicable or within 3 weeks following the injury or surgical intervention. DXA scanning will be performed (following the gathering of informed consent) if it is anticipated that the affected player will be either fully non weight bearing or partially weight bearing for a minimum of 4 weeks as a consequence of trauma, or as a result of any treatment or following any surgical intervention whether for an acute or non-acute injury. Injured participants who fulfill the inclusion criteria will receive a DXA scan of their lumbar spine, both hips, both knees and total body composition as soon as practicable following their injury, then at 6 weeks, 6 months and 1 year post injury to record changes in their BMD in the subsequent weeks and months.

**Dose Estimation**
The following dose estimates have been identified for the proposed DXA scans:

<table>
<thead>
<tr>
<th>DXA</th>
<th>Estimated procedure dose - per attendance (micro Sieverts)</th>
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<tbody>
<tr>
<td>Total Body</td>
<td>0.5 microSv</td>
</tr>
<tr>
<td>Bilateral proximal femora</td>
<td>1.35 microSv (0.68 microSv each)</td>
</tr>
<tr>
<td>Lumbar spine</td>
<td>1.4 microSv (0.7 microSv AP and lateral)</td>
</tr>
<tr>
<td>Bilateral knees</td>
<td>1.4 microSv (0.7 microSv each)</td>
</tr>
<tr>
<td>Hand and wrist</td>
<td>0.1 microSv</td>
</tr>
</tbody>
</table>

The average dose received by the participants at a single DXA attendance is estimated to be between 4 and 6 microSv. Therefore the average total participant dose will be between 12 and 20 microSv, with a dose constraint of 15 microSv to allow for any requiring scanning on thick mode (larger participants).

**Blood Tests**
Fasting blood samples will also be taken during the course of the study in order to observe general bone health. Analysis of the samples obtained will include Calcium regulating hormones; vitamin D, alkaline phosphatase (ALP), testosterone and oestrogen levels as these are all important regulatory hormones involved required for the healthy formation and turnover of bone.

In addition highly sensitive CRP (hsCRP) will also be analysed as this will indicate the presence of any low grade inflammation in non-injured participants. However, hsCRP will not be sampled in the injured group as it is well recognised that CRP levels increase following fracture or soft tissue trauma, therefore hsCRP analysis would be inappropriate in this group. Bloods will be taken according to local protocols and once serum has been extracted will be stored on site securely and at an appropriate temperature, the analysis will occur at a clinical laboratory to ensure consistency and validity of the results.

**Questionnaires and Accelerometer use**
All participants will be asked to complete a questionnaire regarding their general health and any relevant injuries they may have sustained, injured participants will be asked to complete
a validated lower extremity function score questionnaire. The control participants will be asked to wear an accelerometer for a minimum of 7 days in order to assess their physical output over a typical week. They will also be asked to keep an activity diary whilst they wear the device in order to provide some degree of correlation between normal activities and accelerometer data. This data will be collected at some point between baseline and final DXA scans and gathered over a one month period.

Throughout the period of the study training records will be collated to assess the potential effects of the various exercises, and training surfaces where appropriate.

Data analysis

Data collected will be collated and analysed using multi-level modelling. The primary research question will seek to establish what degree of percentage difference is seen in BMD with particular regard to the injured limb, but also to any BMD changes to the hips, knees and lumbar spine as an effect of reduced weight bearing over the period of observation. Blood analysis will also be used to look for any associated changes to general bone health and hormone markers associated with bone turnover. Control groups will have their BMD data collated and correlated with activity levels, BMI, age and blood analysis. Accelerometer data will be examined and the intensity of the exercise levels recorded, this will be cross referenced with activity diaries and club training records where appropriate to look for any correlation between activity levels and BMD measurements. Appropriate statistical testing will be utilised to determine the significance of the observed findings.

QUIS Scanning

All participants will undergo quantitative ultrasound (QUIS) of their heel. This is a simple procedure that only takes a very short amount of time. It will be made clear that the results obtained are not clinically diagnostic because there is no robust evidence base for comparison of results in this population. These findings will therefore contribute towards the development of such an evidence base.

Chart outlining visits and activities during the study
✓ Uninjured participants
✓ Injured Participants

<table>
<thead>
<tr>
<th></th>
<th>First Appointment</th>
<th>6 weeks Injured Participants only</th>
<th>6 months</th>
<th>12 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lumbar spine (DXA)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Both hips (DXA)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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</table>
Summary of main issues.
The main potential risk in this study comes from the ionising radiation used with the DXA scans. The total scan dose for each visit is approximately 4 to 6 micro Sieverts. However, despite the number of scans involved, the dose in total remains relatively low at approximately 20 micro Sieverts over the entire study (for participants who will undergo a maximum of 4 scans during the course of the study). To put this into context, this radiation exposure is roughly equivalent to less than half that which might be expected during a transatlantic flight, or approximately 2 to 3 days unprotected exposure to the sun. All participants will be informed of the radiation dose, the potential risks involved along with equivalent risks to enable them to better understand and quantify the radiation risk to themselves.

DXA scans will be reported by a member of the research team and any abnormal findings, such as an unexpectedly low BMD score, will be reported to the participants’ GP. The participant will have consented to their GP being made aware of their involvement in the study and it is made clear in the participant information sheet that any unexpected findings will be sent directly to the GP. They will not be reported to the participant as it may cause undue concern and distress if the GP subsequently feels that no follow up testing is required. Normal DXA results will be shared directly with the participants if they wish to have them.

Blood samples will be taken and this can cause some discomfort. Complications from blood taking can include haematomas and infection, although this uncommon. The researchers taking blood are appropriately trained and experienced in the process and departmental protocols will be followed to minimise any risk to either the researcher or the participant. Again, if there are unexpected blood results then this information will be passed directly to...
the participants GP for further investigation if appropriate. Blood results which fall within normal ranges will be reported back to participants if they wish to receive them, if appropriate then advice will also be offered with regard to vitamin supplement use.

Potential Impact of the study
This research will enhance the understanding of high volume training in power sports and the long term impact of injury on the bone health of young athletes and whether DXA scanning can provide valuable information in the ongoing care pathway of this demographic in particular, but also in adolescents in general. As DXA is a low dose modality this study will help to establish the potential for BMD analysis to become part of the treatment plan for athletes with lower limb injuries. The avoidance of stress fractures and the exacerbation of injury will help to ensure young athletes can fulfil their potential and in turn reduce unnecessary burden on health services.

Dissemination strategy
In addition to publishing in Radiography, I would aim for at least three further publications in internationally ranked journals: 1) Medicine and Science in Sports and Exercise (impact factor 4.1); 2) BJR or skeletal radiology (impact factor 2.8); and 3) British Journal of Sports Medicine (impact factor 3.5). The aim is to disseminate this work prior to publication at conferences such as UKRC. It is also expected that findings will be disseminated to coaches, parents and players via non-academic channels, i.e. professional body and coaching publications.

References


17. Laura K. Bachrach, Trevor Hastie, May-Choo Wang, Balasubramanian Narasimhan, and Robert Marcus. Bone Mineral Acquisition in Healthy Asian, Hispanic, Black, and Caucasian Youth: A Longitudinal Study. Received: April 05, 1999 Accepted: August 19, 1999 First Published Online: July 01, 2013 The Journal of Clinical Endocrinology & Metabolism Volume 84, Issue 12