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# Epidemiology of bone stress injuries in Australian high performance athletes: A retrospective cohort study

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ABSTRACT

*Objectives:* To examine the epidemiology of bone stress injuries in an elite sports institute.
*Design:* Retrospective cohort study at the Australian Institute of Sport.
*Methods:* A retrospective analysis of the clinical records contained within the Australian Institute of Sport Athlete Management System electronic database was performed. Records with Orchard Sports Injury Classification System codes relating to bone stress injuries and stress fractures were reviewed and descriptive statistics relating to sport, site of injury, athlete age, sex and activity were analysed.
*Results:* In the three-year period January 2014–2017, 11,942 injuries were recorded across 48 sports. 181 bone stress injuries (0.15% of all injuries) were recorded across 16 sports. BSIs in the foot and lumbar spine were the most common accounting for 30% and 23% of all the reported BSIs respectively. Gymnasts had a high frequency of lumbar spine stress injuries (n = 24, 51%) and rowers had a high frequency of rib stress injuries (n = 22, 88%). The most common location for stress injuries, equally distributed across a variety of sports, were in the foot (n = 54, 30%). Female athletes recorded more BSIs than males.
*Conclusion:* Across a three-year period, 0.15% of injuries were related to bone stress injuries. Almost double the cases were recorded in female athletes. Sport specific injury sites were observed in the dataset.


## Practical Implications

- Individual sports recorded BSIs in different body areas, with most sports recording bone stress injuries in the feet.
- Female athletes recorded more BSIs compared to men.
- The majority of BSIs occurred during general training.

## 1. Introduction

Injuries prevent athletes from training and competing which consequently lowers the chance of obtaining their performance goals.[1] Bone stress injuries represent failure of bone to adequately remodel itself to withstand repetitive loading. They occur along a continuum from bone strain with repair through usual mechanisms, through to an accumulation of damage that can result in stress reactions, stress fractures or complete bone fractures.[2] In bone strain, histology can show microscopic cracking and microdamage through to frank cortical fractures.[3] while modern magnetic resonance imaging techniques are now able to detect and grade bone stress injury with changes in bone signal being termed a bone stress reaction and a discrete fracture line indicating a bone stress fracture.[4] Therefore, we will use the term bone stress injury (BSI) to include bone stress reactions and bone stress fractures.

There are limited studies available that describe the aetiology of BSIs, however the evidence that does exist indicates that several intrinsic and extrinsic factors may play a role. Intrinsic risk factors commonly associated with BSIs include female sex,[2] the female athlete triad (FAT),[5] relative energy deficiency syndrome in sport (RED-s)[6] including low energy availability[7] and participation in sport during adolescent growth.[8] Extrinsic factors include participation in weight-bearing sports,[9] completing movements that lead to repetitive loading, and footwear and training surface.[2] Prevention of BSIs is generally by identification and monitoring of athletes at risk based on the identified intrinsic and extrinsic factors.[10]

The Australian Institute of Sport (AIS) is Australia's strategic high performance sport agency.[11] Under this leadership role an elec-

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tronic medical record was introduced following the 2012 London Olympic Games. This e-Health platform (athlete monitoring system — AMS) is the main medical repository for clinical records of injuries and illnesses in Australia's high-performing athletes. To date, 49 sports utilise this platform albeit with differing levels of engagement. This clinical record allows for the retrospective investigation of injuries from data that is routinely collected as part of normal servicing (medical and physiotherapy) practices. This limits selection biases, however, it introduces less control over the data than may be expected during a formal prospective research project. While acknowledging these limitations, the AMS provides an opportunity to examine case-series of injuries that would otherwise not have been systematically recorded.

Brukner et al.[12] presented a systematic inventory of BSIs seen at an Australian sports medicine clinic in 1996. There have been no further Australian studies to confirm their findings, review other groups of athletes nor consider monitoring of BSIs in athletes. The aim of this epidemiological retrospective review was to expand on Brukner et al.[12] by focusing on elite athletes across a number of sports and investigating the utility and limitations of the AMS in monitoring and studying athlete health which may then suggest potential applications for training and injury prevention.

## 2. Methods

Data was sourced from the Australian Institute of Sport's Athlete Management System (AMS), an electronic database, to record training and medical information of high performance athletes. The time period covered in the study was January 2014 to January 2017. All data were de-identified before extraction from the database. The Human Research Ethics Committee of the Australian Institute of Sport (2016/1206) granted ethical approval and the study complies with the Declaration of Helsinki. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE)[13] statement was employed to ensure accurate reporting of epidemiology data and methods.

Records from the AMS were selected for stress injuries and bone stress fractures based on Orchard Sports Injury Classification System (OSICS) codes. OSICS is used for coding injury diagnosis in sport injury surveillance systems, with specific codes for the field of sports medicine.[14] The codes are comprised of four characters. The first character signals the anatomical location of the injury. The second character relates to the specific injured tissue or pathology of the injury. The last two characters describe the pathology of the diagnosis.[15] The second character 'S', stands for stress fracture or bony stress injury (reactions) and was the identifier used for this study. The term stress injury, therefore includes bone stress reactions and stress fractures.

Data extracted on each injury included sport of athlete, age, sex, site, side of injury and activity at time of injury, OSICS code, date of injury, and duration of injury. All data were assessed for normal distribution using the Shapiro–Wilk test. A one-sample proportions test was utilised to investigate whether binary variables (such as side) were overrepresented in the data. All analyses were completed using a custom-made script in Stata (Stata 13 IC, StataCorp, USA).

## 3. Results

In the three-year period January 2014–2017, 11,942 injuries were recorded across 48 sports. 181 BSIs were recorded in 152 athletes in the AIS Athlete Management System (Fig. 1). BSIs represent 0.15% of all reported injuries during this surveillance period. Females had a higher frequency compared to males (females, n = 115, 64%; males, n = 66, 36%). The bony stress injuries were spread across 16 sports and 11 general body sites (Table 1). Age was non-parametric. The median age was 15.8y (IQR, 13.2–19.5, range 10–32 y). The most common activity relating to BSI was domestic training (n = 119, 66%), as opposed to competition (n = 12, 7%), training camps (n = 6, 3%), cross training (n = 3, 2%) or warm up (n = 2, 1%). There was no significant difference between the left and right side (proportion of right side = 0.55, 95%CI 0.46-0.63, z = 1.07, p = 0.29), in regards to BSIs in this study.

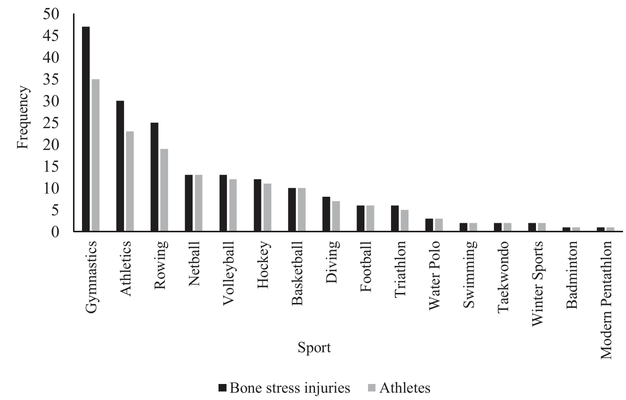


**Fig. 1.** Frequency of bone stress injuries and athletes per sport.

Twenty-three athletes (15%) recorded two or more unique BSI across the three-year study period. Multiple BSIs were recorded in athletes in gymnastics (n = 9), athletics (n = 5), rowing (n = 5), volleyball (n = 1), hockey (n = 1), diving (n = 1), and triathlon (n = 1). Three BSIs were recorded in one gymnast and one rower. Four BSIs were recorded in one gymnast and one athletics athlete.

The sport with the most recorded BSIs was gymnastics with 47 injuries spread over 35 athletes, 24 (51%) of which were in the lumbar spine (Table 1). Athletics recorded 30 BSIs across 23 athletes, all located in the lower body (foot, n = 9; lower leg, n = 9; lumbar spine, n = 4; thigh, n = 3; buttock/pelvis, n = 3; ankle, n = 2). Rowing had the third highest number of BSIs with 24 recorded injuries across 19 athletes, with the ribs being the most common site (n = 22). Across all sports, the foot was the most common site for development of a BSI, representing 30% of all BSIs, with 54 injuries. The lumbar spine was also frequently involved with 42 records as was the lower leg and knee with 34 injuries.

## 4. Discussion

This review found that BSIs occurred over a wide range of sports, with each sport recording injuries at certain sites. Gymnastics, athletics and rowing recorded the highest frequency of BSIs. These results were consistent with previous cross-sport studies of various populations of athletes that showed gymnastics and athletics to record the highest frequency of BSIs.[16] BSIs usually exclude athletes from participation for weeks at a time[17] disrupting training and competition schedules. To reduce the impact on athletes proper monitoring and prevention is essential.

The aetiology of BSIs is not well studied, however, many intrinsic and extrinsic risk factors have been identified.[2] In addition to improper technique and biomechanics, conditioning, volume, intensity and a history of BSIs,[18] female sex and FAT are intrinsic risk factors for BSIs.[2,5] The components that make up the FAT include low energy availability, low bone density and amenorrhoea.[19] Tenforde et al.[19] found that female athletes with moderate- or high-risk Female Athlete Triad Cumulative Risk Assessment Scores were at greater risk of sustaining bone stress injuries and in their study of female college athletes, 56% of gymnasts, 49% of cross-country runners and 20% of rowers fell into these categories. Female athletes

**Table 1**
Frequency of bone stress injuries by sport and injury site.

| | Athletics | Badminton | Basketball | Diving | Football | Gymnastics | Hockey | Modern Pentathlon | Netball | Rowing | Swimming | Taekwondo | Triathlon | Volleyball | Water Polo | Winter Sports | Total per site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Athletes (n)** | 23 | 1 | 10 | 7 | 6 | 35 | 11 | 1 | 13 | 19 | 2 | 2 | 5 | 12 | 3 | 2 | 152 |
| **Foot** | | | | | | | | | | | | | | | | | 54 |
| Foot | 2 | | 1 | | 1 | 1 | 3 | 1 | 1 | 1 | | 1 | | 2 | | | 14 |
| Metatarsal | 5 | | 4 | 2 | 1 | 4 | 3 | | 2 | 1 | | 1 | 1 | | | | 24 |
| Sesamoid | 2 | 1 | | | | 2 | 3 | | 5 | | | | | | 1 | | 14 |
| Navicular | | | | | | 2 | | | | | | | | | | | 2 |
| **Ankle** | | | | | | | | | | | | | | | | | 10 |
| Ankle | | | 2 | | | 1 | | | | | | | 1 | 2 | | | 6 |
| Calcaneus | 2 | | 1 | | | | | | | | | | 1 | | | | 4 |
| **Lower Leg and Knee** | | | | | | | | | | | | | | | | | 34 |
| Fibula | 1 | | 1 | 1 | | 4 | 1 | | 2 | | | | | 1 | | 2 | 13 |
| Tibia | 4 | | 1 | | | 4 | 1 | | 2 | | | | 1 | 2 | | | 15 |
| Posteromedial tibia | 4 | | | 1 | | 1 | | | | | | | | | | | 6 |
| **Thigh** | | | | | | | | | | | | | | | | | 7 |
| Femoral shaft | 3 | | | | | 1 | | | | | | | 1 | 2 | | | 7 |
| **Hip and Groin** | | | | | | | | | | | | | | | | | 1 |
| Femoral neck | | | | | | | | | | 1 | | | | | | | 1 |
| **Buttock and Pelvis** | | | | | | | | | | | | | | | | | 5 |
| Pelvis | 1 | | | | | | 1 | | | | | | | | | | 2 |
| Ischium | | | | | 1 | | | | | | | | | | | | 1 |
| Sacrum | 2 | | | | | | | | | | | | | | | | 2 |
| **Lumbar Spine** | | | | | | | | | | | | | | | | | 42 |
| Lumbar pedicle | 1 | | | | | | | | | | | | | | | | 1 |
| Lumbar spine | 2 | | | 2 | 3 | 19 | | | 1 | | 1 | | | 3 | 1 | | 32 |
| Multiple pars | 1 | | | 1 | | 3 | | | | | | | | | | | 5 |
| Pars interarticularis | | | | | | | | | | | | | | | 1 | | 1 |
| Pars L5 | | | | | | 2 | | | | | | | | 1 | | | 3 |
| **Forearm and elbow** | | | | | | | | | | | | | | | | | 4 |
| Radius/ulna | | | | | | 1 | | | | | | | | | | | 1 |
| medial ulna | | | | | | 2 | | | | | | | | | | | 2 |
| Elbow | | | | 1 | | | | | | | | | | | | | 1 |
| **Chest** | | | | | | | | | | | | | | | | | 24 |
| Rib | | | | | | | | | | 22 | 1 | | 1 | | | | 24 |
| Total bone stress injuries | 30 | 1 | 10 | 8 | 6 | 47 | 12 | 1 | 13 | 25 | 2 | 2 | 6 | 13 | 3 | 2 | 181 |

represented 64% of the reported BSIs within the AMS, supporting female sex and the FAT as risk factors for BSIs.[2,5]

Low energy availability, or more specifically, REDS-S is another intrinsic risk factor.[6,7] RED-S expands on the three factors considered in the FAT and provides a more comprehensive framework to account for a mismatch between energy intake and expenditure, and the physiological and psychological consequences.[6] The new nomenclature also recognises that RED-S is something that affects male and female athletes.[6] Bone health continues to be recognised as a physiological consequence of this mismatch. The IOC consensus statement on FAT and RED-S[6] highlights that bone loss in athletes who have relative energy deficiency can be irreversible with one consequence being an increased risk of BSIs. In a smaller sample of the population included in this study, approximately 50% of female athletes scored above the clinical cut-off for low energy availability (as measured by the LEAF-Q).[20] Prevention of BSIs due to RED-S, and other intrinsic risk factors, is primarily through identification of athletes at risk.[10] For male and female athletes, a monitoring program aimed at early detection for signs of energy deficiency may help to identify athletes in the high-risk category.[6,19]

Extrinsic risk factors for BSIs are generally based on the environment in which a sport is played in and the components of the sport itself. Environmental factors can include seasonality, indoor/outdoor setting or training surface.[2] Sport factors can include team/individual sports, weight-bearing activities,[9] movements with repetitive loading, footwear[2] or high/low impact activities. Of the high impact sports, gymnastics was the most represented, followed by athletics. Lumbar spine injuries accounted for 51% of the BSIs in gymnasts (Table 1). Previous studies have found that elite female gymnasts more commonly show degenerative disc changes and lower back injuries compared to the general population of the same age[21] and that the lower back is by far the most common site of injury.[22] Lower back injuries account for anywhere between 12 and 16% of all injuries in women's gymnastics[21,22] with lumbar spine BSIs comprising a significant portion of these injuries. The American Medical Society for Sports Medicine issued a position statement on overuse injuries[8] highlighting the increased risk for overuse injuries during the period of adolescent growth, which is particularly relevant to the sport of gymnastics.

Bone stress injuries in athletics were predominantly located in the lower limbs, particularly the foot and lower leg. Footwear is one extrinsic factor that is consistently reported as a risk factor BSIs,[2] in particular the role it can play in shock absorption and foot and ankle stability.[2] Further research into athletic footwear and its ability to absorb shock, influence biomechanics such as foot strike pattern and reduce BSI risk is required as there are limited current studies.[23] Up to date research in this area is particularly important as footwear design is an evolving field with trends such as minimalist shoes and barefoot running providing increased variety in the market. While these equipment factors play a role, the workloads undertaken by these athletes is likely to play a significant role in the aetiology of these injuries.[24]

Of the low-impact sports, rowing had the highest representation with 24 recorded BSIs over the study period. The site of injury in this sport was very homogenous with 22 of the 24 BSIs recorded in rowers located in the ribs. Of the 22 rib stress injuries, 18 injuries occurred in 14 female athletes (82%) and 4 occurred in 3 male athletes (18%). RSIs are common in elite rowers, with an estimated incidence of approximately 9%.[25,26] A 2015 systematic review by D'Ailly et al.[27] of RSIs in rowing found insufficient or conflicting evidence for all studied risk factors. This included changes in training program, incorrect technique, female gender, low bone mineral density, inadequate equipment and training type. A 2018 review found some emerging evidence on low energy availability and RED-S but reported that there continues to be limited research and evidence of risk factors and sinjury mechanisms for RSIs in rowers.[28] The high prevalence reinforces the importance of prevention[25,26] and highlights that low-impact sports that include extensive repetitive movements with load are at risk of BSIs.

This discussion has focused on external and internal physical risk factors that may contribute to BSIs. Hughes et al.[3] have proposed an alternate approach to categorising the modifiable risk factors for BSIs, dividing them up in to factors that affect the load on bone, factors that influence baseline bone stiffness and factors that inhibit or promote the adaptive response to bone loading. Under factors that inhibit or promote adaptive response to bone loading, sleep and psychological factors are considered.[3] Psychological factors can influence risk of sustaining a BSI as well as recovery.[29,30] Psychological stressors such as self-blame, ineffective coping with stress, anxiousness and stressful life events can impact on performance and increase risk of injury.[29,30] Young athletes were found to be at increased risk of experiencing psychological stressors in some studies[29] but not all.[30] In addition to age, gender was another factor that was considered in studies on psychological impact on overuse injury risk. Gender was not found to be a consistent risk factor across the studies.[30,31]

There were several limitations in this study. As the study utilised clinical records it did capture real world data, however, the ability to control what was recorded was lost. National sporting organisations can choose to opt in to the AMS, as such it is not routinely used by all clinicians across all sports. This means that during the study period some athletes were not under surveillance causing an underreporting bias within some sports over the study period. Due to the manner of athlete funding, athletes enter and exit programs depending on their success. This created the potential to miss recording injuries that occurred during a period within the study when an athlete was not on scholarship and therefore not monitored under the AMS. Combined, these limitations mean that it is likely that some BSIs were not captured in the AMS leading to an under-reporting of this injury at the AIS. This under-reporting is more likely to lead to bias on a sport-to-sport basis as opposed to bias by age or gender.

As the AMS is not a definitive record of AIS athletes a significant limitation of this study was that data on the entire cohort of athletes and their availability were not captured and risk and accurate incidence density could not be measured.

## 5. Conclusions

A review of BSIs recorded in an elite sport institution over a three-year period showed that

BSIs occurred over a range of sports, with each sport at risk for injury at certain sites. In particular gymnasts are at risk of developing BSIs in the lumbar spine, field and track athletes in the lower limbs and rowers in the ribs. Female athletes are also more likely to present with BSIs than male athletes.

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## References

1. Drew MK, Raysmith BP, Charlton PC. Injuries impair the chance of successful performance by sportspeople: a systematic review. *Br J Sports Med* 2017; 51(16):1209–1214.
2. Pepper M, Akuthota V, McCarty EC. The pathophysiology of stress fractures. *Clin Sports Med* 2006; 25(1):1–16.
3. Hughes JM, Popp KL, Yanovich R et al. The role of adaptive bone formation in the etiology of stress fracture. *Exp Biol Med* 2017; 242:897–906.

4. Saunier J, Chapurlat R. Stress fracture in athletes. *Joint Bone Spine* 2018; 3:307–310.
5. Barrack MT, Gibbs JC, De Souza MJ et al. Higher incidence of bone stress injuries with increasing female athlete triad–related risk factors: a prospective multisite study of exercising girls and women. *Am J Sport Med* 2014; 42(4):949–958.
6. Mountjoy M, Sundgot-Borgen J, Burke L et al. The IOC consensus statement: beyond the Female Athlete Triad – Relative Energy Deficiency in Sport (RED-S). *Brit J Sports Med* 2014; 48(7):491.
7. Melin A, Tornberg ÅB, Skouby S et al. The LEAF questionnaire: a screening tool for the identification of female athletes at risk for the female athlete triad. *Br J Sports Med* 2014; 48(7):540–545.
8. DiFiori JP, Benjamin HJ, Brenner JS et al. Overuse injuries and burnout in youth sports: a position statement from the American Medical Society for Sports Medicine. *Br J Sports Med* 2014; 48:287–288.
9. Bennell KL, Malcolm SA, Thomas SA et al. The incidence and distribution of stress fractures in competitive track and field athletes: a twelve-month prospective study. *Am J Sport Med* 1996; 24(2):211–217.
10. Chen YT, Tenforde AS, Fredericson M. Update on stress fractures in female athletes: epidemiology, treatment and prevention. *Curr Rev Musculoskelet Med* 2013; 6(2):173–181.
11. Australian Institute of Sport. *What is the AIS?*, Canberra, AIS, 2013,. (Accessed July 2017) http://ausport.gov.au/ais/about.
12. Brukner P, Bradshaw C, Khan KM et al. Stress fractures: a review of 180 cases. *Clin J Sports Med* 1996; 6:85–89.
13. Von Elm E, Altman DG, Egger M et al. The Strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *Int J Surg* 2014; 12(12):1495–1499.
14. Orchard J, OSICS. Available at: http://www.johnorchard.com/about-osics.html. (Accessed July 2017).
15. Finch CF, Orchard JW, Twomey DM et al. Coding OSICS sports injury diagnosis in epidemiological studies: does the background of the coder matter? *Br J Sports Med* 2014; 48:552–556.
16. Rizzone KH, Ackerman KE, Roos K et al. The epidemiology of stress fractures in collegiate student-athletes, 2005-2005 through 2013-2014 academic years. *J Athlet Tr* 2017; 52(10):966–975.
17. Nattiv A, Kennedy G, Barrack MT et al. Correlation of MRI grading of bone stress injuries with clinical risk factors and return to play: a 5-year prospective study in collegiate track and field athletes. *Am J Sport Med* 2013; 41(8):1930–1941.
18. Miller T, Harris L, Kaeding JD et al. Stress fractures of the ribs and upper extremities: causation, evaluation and management. *Sport Med* 2013; 43(8):665–674.
19. Tenforde AS, Carlson JL, Chang A et al. Risk assessment stratification to the development of bone stress injuries in collegiate athletes. *Am J Sport Med* 2016; 45(2):302–310.
20. Drew M, Vlahovich N, Hughes D et al. Prevalence of illness, poor mental health and sleep quality and low energy availability prior to the 2016 Summer Olympic Games. *Br J Sports Med* 2018; 52(1):47–53.
21. Bennett DL, Nassar L, DeLano MC. Lumbar spine MRI in the elite-level female gymnast with low back pain. *Skeletal Radiol* 2006; 35:503–509.
22. Sands WA, Shultz BB, Newman AP. Women's gymnastics injuries: a 5-year study. *Am J Sport Med* 1993; 21(2):271–276.
23. Giandolini M, Arnal PJ, Millet GY et al. Impact reduction during running: efficiency of simple acute interventions in recreational runners. *Eur J Appl Physiol* 2013; 113:599–609.
24. Jacobsson J, Timpka T, Kowalski J et al. Injury patterns in Swedish elite athletics: annual incidence, injury types and risk factors. *Br J Sports Med e* 2013; 47(15):941–952.
25. McDonnell LK, Hume PA, Nolte V. Rib stress fractures among rowers: definition, epidemiology, mechanisms, risk factors and effectiveness of injury prevention strategies. *Sports Med* 2011; 41(11):883–901.
26. Vinther A. Rib stress fractures in rowers. *BMC Sports Sci Med Rehabil* 2015; 7(S1):18.
27. D'Ailly PN, Sluiter JK, Kuijer PP. Rib stress fractures among rowers: a systematic review on return to sports, risk factors and prevention. *J Sport Med Phys Fit* 2015; 56(6):744–753.
28. Thornton JS, Thornton JS, Vinther A. Prevention of rib stress injury in rowers. What do we know and where do we need to go? *Sports Orthop Traumato* 2018; 34(3):278–286.
29. Laux P, Krumm B, Diers M et al. Recovery-stress balance and injury risk in professional football players: a prospective study. *J Sports Sci* 2015; 33(20):2140–2148.
30. Timpka T, Jacobsson J, Dahlström Ö et al. The psychological factor 'self-blame'predicts overuse injury among top-level Swedish track and field athletes: a 12-month cohort study. *Br J Sports Med* 2015; 49(22):1472–1477.
31. Vetter RE, Symonds ML. Correlations between injury, training intensity, and physical and mental exhaustion among college athletes. *J Strength Cond Res* 2010; 24(3):587–596.