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## Contents



# Editorial: Quantification, clarification and standardisation of whole body vibration.

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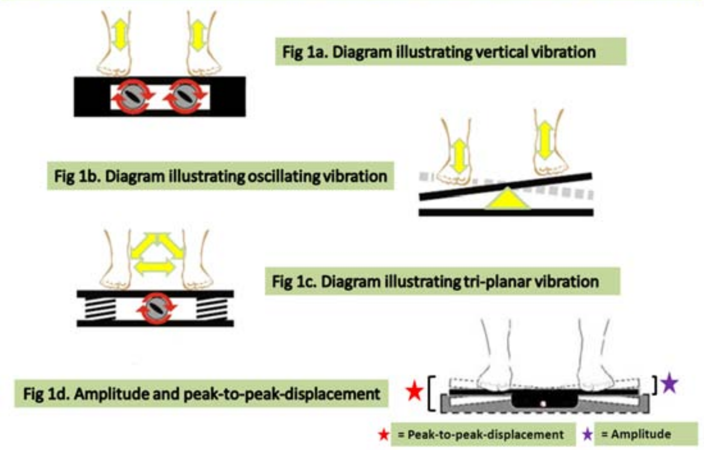
Vibration is defined as a mechanical stimulus characterised by a recurring oscillatory motion back and forth over the same pattern. We experience vibration throughout our daily lives when driving a car or operating machinery with motorised parts, and exposure is traditionally associated with negative effects on the human body. However, whole body vibration (WBV) is an intervention that has gained popularity in both the medical and sporting arenas in recent years. Despite its popularity though, it would appear that our understanding of how human systems respond to these vibratory signals lags somewhat behind the availability of the WBV platforms used for training, and that inconsistencies and inaccuracies reported regarding WBV have the potential to limit the replication and development of research. There is also concern that researchers, by inadvertently using incorrectly reported protocols from previous studies, may unknowingly expose participants to harmful interventions. The aim of this editorial, therefore, is to quantify, clarify, and standardise the terminology used to describe WBV training.

The most common way of receiving vibration, as a specific training modality, is via a vibration platform (or vibration plate). Depending on the manufacturer and design specifications, these platforms operate in movements, which can be classified as either linear (vertically only), oscillating (moving vertically on alternate sides in a seesaw-like manner) or tri-planar (moving through all three axis) (Figures 1a-1c). WBV is believed to stimulate the primary endings of the muscle spindle (Ia. afferent), which excites the motor-neurons, causing contraction of homonymous motor units, resulting in a tonic contraction of the muscle; known as the tonic vibration reflex. Potential adaptations following vibration training include: increased excitation of peripheral and central structures (pre-activation of the musculoskeletal system, resulting in improved readiness for the training stimulus); increased synchronisation of motor units; stimulation of golgi tendon organs (GTO), inhibiting activation of antagonist muscles; altered hormonal secretion; variation of neurotransmitter concentrations (dopamine, serotonin); and excitation of sensory receptors such as muscle spindles, leading to improvements in the stretch reflex cycle. These adaptations have manifested in a range of improvements

**Figures 1a – 1c. Different types of vibration platforms available**
**Fig 1d. Difference between amplitude and peak-to-peak-displacement**

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(superior jumping and sprinting performance; increased flexibility and balance; reduced delayed onset muscle soreness and cortisol levels; greater resistance to fatigue; in addition to enhanced bone health through heightened activation of osteoblast cells) in a variety of populations (sedentary individuals; athletes; those suffering from multiple sclerosis, cerebral palsy, fibromyalgia, rheumatoid arthritis and ankylosing spondylitis; and those at increased risk of osteoporosis, such as post-menopausal women and older people). Subsequently, WBV has been incorporated into training regimes, rehabilitation and preventative health promotion strategies.

The intensity of WBV training can be manipulated by altering the frequency and/or amplitude of oscillations to ultimately affect the magnitude/acceleration of the vibratory signals. The frequency of WBV is regularly reported, and there is very little confusion regarding its interpretation; it simply quantifies the number of impulses (hertz or Hz) delivered every second (the repetition rate of the cycles). The majority of linear and tri-planar WBV platforms have a frequency range from 15 to 60 Hz, while oscillating platforms typically operate at frequencies below 30 Hz. Platforms do not generally operate below a frequency of 10Hz, as at this frequency there is the risk of interfering with the body's natural resonance; potentially having serious health implications. There currently exists a lack of clarity however regarding the use of the term amplitude, which has been interchangeably used with other terminology, such as peak-to-peak-displacement. The amplitude of the platform corresponds to the extent of the vertical displacement from the centre point of movement. Platforms generally report a range of 1-15mm, although a number have fixed or set amplitude. Conversely, peak to peak displacement (mm) differs from amplitude in that it encompasses the full range of displacement (Figure 1d). The magnitude refers to the acceleration of the movement and is measured in g's, or magnitudes of gravity. The acceleration that a body experiences while on a vibration platform can be accurately estimated using the equation shown in Figure 2. (Where a is the acceleration experienced expressed as the equivalent of the acceleration of earth's gravity [9.81 $m.s^{-2}$]; A is the amplitude of the vibration; and f is the frequency of the vibration). For this formula to work effectively it is vital that all the separate variables are calculated using corresponding units. Therefore it is important that all the separate variables are calculated using corresponding units. For example, the components of A and g must have the same unit of length (SI Unit for length is the metre [m]); therefore, with a frequency of 35Hz and amplitude of 2mm, the formula will be calculated according to the process shown in Figure 4. A variety of positions can be adopted on the vibration platform; the most commonly used being squats (static/dynamic and deep/shallow), lunges and calf raises. While the positions utilised on the platform will be dependent on the specific region being trained (e.g. deep squats for developing the quadriceps muscles), the positioning of the feet, when using oscillating machines, is especially important (and crucial with regard to reporting protocols for future study) as these will have an effect on the amplitude the user is exposed to (refer to Figures 1a-1d: feet positioned more laterally will be exposed to a greater amplitude and acceleration). Other variables, which can be manipulated, are the duration of the time spent on the device (usually ranging from 30 to 240seconds in one bout), and the addition of any external loading (e.g. dumbbells or barbells as used in traditional weight-training). While WBV has been reported to be a safe method of exercise, it is not recommended for certain populations including (but not limited to): pregnant women; those with recent or possible thrombosis; cardiovascular complaints (valve disorder, advanced arthrosis, arthropathy); acute RA; recent sutures, scars and fresh wounds; foot, knee and hip implants; metal/synthetic implants (incl. pacemaker); lumbar disc problems; acute inflammations or infections; migraine headaches; osteoporosis of the lumbar vertebrae; and epilepsy. While WBV appears to have the potential to provide beneficial effects in both performance and health, ensuring the standardisation of variable reporting (especially amplitude/peak-to-peak-displacement and acceleration), is crucial to ensure, not only the development of research but also the safety and well-being of patients, clients and participants.

**Figure 2. Formula for calculating acceleration**

$$a = \frac{A^* (2\pi f)^2}{g}$$

Figure 3. Example of magnitude calculations used for WBV training

$$a = \frac{0.002^* (2\pi\ 35)^2}{9.81} \rightarrow a = \frac{0.002^* (219.9)^2}{9.81}$$

$$\downarrow$$

$$a = \frac{96.7}{9.81} \leftarrow a = \frac{0.002^*\ 48361}{9.81}$$

$$\downarrow$$

$$a = 9.86$$

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# Welcome to Volume 5 (Issue 1) of the JST

Welcome to Issue 1 (Volume 5) of the Journal of Sports Therapy. This issue includes contributions from a range of professionals and academics. On-going features on osteoporosis and research methods continue; focusing on diagnostic techniques, and concepts relating to quantitative inputs and outputs, respectively. A paper on the characteristics of professional footballers pre- and post- season fitness levels continues recent coverage of the monitoring and assessment of sports performers. A case study of an adverse event following acupuncture and an article discussing the muscle recruitment of the scapulae during therapeutic exercise should provide interesting reading for those in practice; while articles regarding weight loss and dehydration in futsal and ankle bracing in basketball should appeal to those with a passion for performance enhancement and injury reduction. Once again, the diversity of the papers presented in this issue continues to highlight the inter- and multi- disciplinary aspirations of the journal, while its volume is an indication of the journal's continuing development and popularity. With an imminent improvement and enhancement of the website and services offered by the JST, and with our inaugural conference/symposia in the pipeline, it is a very exciting time for all those involved with the journal. We are therefore keen to further involve our readers in this development. Also, the next issue will be our first 'pre-Olympic' publication; therefore we especially welcome any Olympic/Paralympic-related articles/features. We, as an editorial team, continue to encourage JST readers to contribute to the journal in a number of ways; be this through submitting articles (original research, reviews or case studies), commenting on previous issues, or providing book and product reviews. We particularly encourage you to have your say regarding the current, and future, state of sports therapy. Inviting scholarly and professional input creates a forum for discussion and a means to connecting with the wider community. For further details or comments, please contact the editor.

**Yours in science and health**
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**Original research**

# Scapular muscle recruitment during therapeutic exercise

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**KEY WORDS**

PNF
Shoulder Strengthening
Scapular Strengthening

**ABSTRACT**

Proprioceptive neuromuscular facilitation (PNF) patterns have been used to improve muscle strength and may facilitate muscle recruitment patterns typically seen during overhead activities. The purpose of this study is to compare scapula muscle activity during commonly used scapular strengthening exercises. Ten healthy men and twenty healthy women between the ages of 18 and 23 participated in the study (n=30, mean age 23 ± 4 yrs., mean height 1.69 ± 0.16m, mean mass 72.6 ± 15 kg). Prior to enrollment in the study, subjects were screened for inclusion and exclusion criteria, which included no history of shoulder pathology were recruited for this study. All participants performed the following exercises while surface EMG recorded the activity of the scapula muscles: (1) seated row, (2) push-up with a plus, (3) D1 flexion PNF and (4) D2 flexion PNF pattern. The main outcome measures were: average percent maximum voluntary isometric contraction (MVIC) of middle trapezius, lower trapezius, upper trapezius and serratus anterior muscle during each exercise. When performing the D2 PNF exercise, middle trapezius was more active compared to the row (p=0.012) and the D1 PNF exercise (p<0.001). There were no differences in serratus anterior activity (p>0.05). The ratio between upper trapezius to lower trapezius was higher during the PNF exercises versus the throw (p<0.05). These results suggest that the D2 flexion exercise is most efficient for recruiting the middle trapezius and serratus anterior, but it does not encourage ideal intra-muscular activation of the scapular muscles as compared to an overhead activity.

The shoulder is estimated as being the site of 16% of all musculoskeletal complaints of pain (Urwin et al., 1998). Among shoulder injuries, impingement syndrome is the most common diagnosis comprising nearly one third of all physician visits (Ludewig and Cook, 2000). The overhead athlete has been shown to be particularly susceptible to shoulder impingement (Burkhart, 2003).

In overhead athletes, evidence suggests that impaired scapular muscle function is associated with the development and progression of impingement symptoms (Meislin et al., 2005; Cools et al., 2005). Studies have linked shoulder impingement with serratus anterior (SA) and upper trapezius (UT) muscle recruitment imbalances that occur during overhead activities (Meislin et al., 2005; Cools et al., 2005). In the overhead athlete diagnosed with impingement, Ludewig and Cook (2000) concluded that the imbalance in the muscle recruitment activity rather than global weakness of the scapular muscles contributed to the athletes' dysfunction. Cools et al. (2007a) reported that athletes with impingement syndrome had greater activity of the UT along with a decrease in activity of the middle trapezius (MT). Studies have also reported a decrease in SA muscle activity that can cause a reduction in scapula upward rotation and protraction (Ludewig and Cook, 2000; Cools et al., 2005). In light of these findings of UT hyperactivity and associated decreases in activity of the MT and SA, rehabilitation protocols for athletes with impingement typically include exercises that maximize activity in the MT and SA while minimizing activity in the UT.

Several studies have analyzed the effectiveness of commonly prescribed scapular strengthening exercises relative to total muscle activation, (Ekstrom et al., 2003; Moseley et al., 1992; Padua et al., 2004) while other researchers have compared these exercises in relation to intra-muscular activity ratios (Ludewig et al., 2004; Cools et al., 2007b). Most commonly, researchers have focused on exercises that target specific muscle function (i.e. dumbbell rows to target scapular retractors, and push-ups with a plus to target scapular protractors) (Ekstrom et al., 2003; Ludewig et al., 2004; Padua et al., 2004; Cools et al., 2007b). Although these studies demonstrate the effectiveness of specific exercises aimed at targeting isolated muscle function, they do not account for the multi-planar activity of the upper extremity during functional movement (Inman et al., 1996; Terry and Chop, 2000).

Diagonal exercises following proprioceptive neuromuscular facilitation (PNF) patterns require the simultaneous activation and coordination of multiple muscle function to produce movement, as is required during an overhead activity (Kisner and Colby, 2002). The philosophy of this approach to exercise is that the strong muscles of a diagonal pattern of movement facilitate the responsiveness of the weaker muscles. As the overhead throw is an extremely complex activity, exercises should be prescribed that meet the muscular demands. Because they facilitate integrated muscle function through a wide range of scapular motion, PNF exercises might be best suited to train the overhead athlete with shoulder impingement. However, studies comparing these diagonal exercises to other commonly prescribed strengthening exercises are lacking.

The purpose of this study is to compare scapula muscle activity during various strengthening exercises. We hypothesized that PNF patterns would not produce significantly different recruitment of the SA and MT when compared to the upright row and push-up with a plus exercises, respectively. In addition, we hypothesized that scapular muscle activity ratios during a PNF exercise would not be significantly different than the ratios during an overhead throw.

## Methods

### *Participants*

Ten healthy men and twenty women between the ages of 18 and 23 participated in the study (n=30, mean age 23±4 y/o, mean height 1.69±0.16m, mean mass 72.6±15 kg). Prior to enrollment in the study, subjects were screened for inclusion and exclusion criteria. The inclusion criteria for this study included: (a) no history of shoulder pain or injury within the past six months, (b) no participation in a shoulder exercise program in the previous six months, and (c) history of participation in an overhead throwing sport at the high school or intercollegiate level. The exclusion criteria included: (a) history of any surgery of the dominant shoulder, (b) history of cervical spine injury, and/or (c) physician diagnosis of any neuromuscular disease of the upper extremity. Subjects who qualified for the study were scheduled to participate in two sessions held over consecutive days.

### *Day 1: Education Session*

During the first visit, subjects read and signed the informed consent form approved by the Institutional Review Board. The purpose of the first visit was to train individuals to perform each exercise with correct technique and to determine the appropriate weight that each would use during data collection. Subjects viewed a short video demonstrating correct completion of each exercise. All exercises were performed with their dominant arm, defined as the person's self-selected arm which they would use to throw a baseball overhand a maximal distance. Subjects were required to perform each exercise correctly as determined by the study administrator. A 10 repetition maximum (RM) was determined for each exercise with the exception of the push-up with a plus exercise. The 10 RM was determined as the maximum amount of weight that could be held while ten repetitions were performed. The weight from the 10 RM was then used the next day during data collection.

### *DAY 2: Data Collection*
### *EMG Set-up*

Electromyographic (EMG) activity was sampled at 2400 HZ using Noraxon equipment (Noraxon Inc, Scottsdale, AZ.) to measure muscle activity for the SA, UT, MT, and lower trapezius (LT) muscles during each exercise. Each set of bipolar recording electrodes from each of the four muscles was connected to a Noraxon Myosystem 2000 electromyographic receiver. All raw myoelectric signals were preamplified (overall gain, 1000; common-mode rejection ratio, 115 dB; signal-to-noise ratio, <1 μV RMS baseline noise, and filtered to produce a bandwidth of 10-1000 Hz).

To reduce the impedance during data collection, the areas where electrodes were placed were shaved of any excess hair, if necessary, and then debrided with an alcohol pad. Electrode placement for the SA was on the eighth rib, two centimeters anterior to the mid-axillary line (Basmajian and Deluca, 1985). The UT electrode was placed on the superior aspect of the shoulder, on the palpable mass of the trapezius. The MT electrode was placed at the level of T2, at the midpoint between the medial side of the scapula and the vertebrae and the LT electrode was placed at the level of the inferior angle of the scapula, midway between the spine and the medial border of the scapula. When electrode placement was complete, each subject performed a maximal contraction to get the 100% maximum voluntary isometric contraction (MVIC) for each muscle using standard manual muscle test procedures (Kisner and Kolby, 2002).

### *Exercise Data Collection*

Muscle activity was recorded during five repetitions of each exercise consecutively, followed by a one minute break before beginning the next exercise. The speed of the motions was regulated using a metronome. For each exercise, one repetition lasted for two seconds. The order of testing was randomized. The exercises that were performed were a seated row, a push-up with a plus, PNF pattern D1 flexion, and PNF pattern D2 flexion.

A video camera was used to synchronize the exercise movements with the EMG for analysis purposes. The upright row exercises were performed using a Biodex (Biodex Medical Systems, Shirley, NY) cable column and pulley system to provide resistance. All other exercises used hand held dumbells for resistance. The push-up exercise was performed without any additional load.

**Seated Row.** The seated row was performed with the subject sitting on a stable surface, with the feet flat on the floor. The resistance from the cable column was applied directly at the level of the chest, and the starting position was with the subject sitting upright with the arms fully reached out in front of them with the hands placed directly next to the cord on the exercise bar. A single repetition consisted of the subject pulling the bar in to the chest, emphasizing scapular retraction at the end range.

**Push-up Plus.** The push-up with a plus was performed on the floor, using the subject's body weight as resistance. The starting position was with the subject supporting their body weight on their arms, hands directly below the shoulders, and elbows flexed. They then pressed up and gave an extra protraction motion at the end when the elbows were fully extended to complete the repetition.

**PNF D1.** The PNF D1 flexion began with the shoulder abducted, shoulder fully internally rotated, elbow extended, forearm pronated and wrist extended. The motion began with wrist flexion, shoulder external rotation with forearm supination, then shoulder adduction and flexion to the finishing position where the arm came to a line directly through the nose.

**PNF D2.** The PNF D2 flexion pattern began with the hand in front of the contralateral anterior superior iliac spine, with the shoulder fully internally rotated, elbow extended, forearm pronated and wrist flexed. The motion consisted of wrist extension, shoulder external rotation and forearm supination, followed by shoulder flexion and abduction to the finishing position with the arm directly in line with the starting position.

**Overhead Throw:** After each exercise was performed, a throw was performed to compare muscle recruitment ratios to a common functional activity often seen in impingement patients. The throw was performed with a tennis ball, thrown approximately 20 feet. The subject was instructed to throw at about 50% of their maximal throw strength, and this was performed five times.

***Data Analysis***

EMG data was collected from the UT, MT, LT, and SA for each exercise. Before analyzing the data, it was rectified, filtered, and normalized to the MVIC for comparisons. A Butterworth filter was used with a high pass filter set at 30 hz, and a low pass filter set at 350 hz. The average muscle activity during each repetition was determined using Noraxon Software. Muscle activity ratios were calculated by dividing the normalized average activity between the appropriate muscles (UT/MT, UT/LT, MT/LT) for each trial.

**Statistics**

Means and standard deviations were determined across subjects within each exercise for each individual muscle (SA, UT, MT, LT) as well as the muscle ratios. Differences in muscle activity between each exercise were analyzed with four, one-way analysis of variances (ANOVA) with repeated measures. In addition, repeated measures ANOVAs were used to compare the muscle activity ratios during the PNF exercises and the throwing activity. In the presence of a main effect, a post hoc analysis was performed using a Bonferroni procedure. All statistical analysis was performed with the Statistical Package for Social Sciences (SPSS) version 16. Alpha was set at 0.05.

**Results:**

*Average EMG activity*

After analyzing the data, there was as a significant main effect in comparisons of MT activity during each of the four exercises ($P<0.001$). Using the post hoc Bonferroni's procedure, it was demonstrated that the D2 flexion diagonal elicited significantly more MT EMG activity versus D1 ($P<0.001$), the row ($P=0.018$), and the push-up with a plus exercise ($P=0.012$). MT activity was significantly lower in the D1 versus the row ($P=0.005$) (Table 1). The row and push-up with a plus had significantly lower UT activity as compared to both PNF patterns ($P=0.001$, D1 and $P=0.008$, D2). LT activity was relatively low during the D1, D2, and push-up with a plus exercise with only the row exhibiting significantly higher activity levels ($P=0.0034$). Regarding SA muscle activity, no significant differences ($P=.068$) were present between the PNF patterns or the push-up with a plus exercise. However, SA muscle activity was significantly lower during the row exercises versus both PNF exercises ($P=0.005$)(Table 1).

**Table 1. Average EMG Muscle Activity**

| | D1 | D2 | Row | Push-up |
|---|---|---|---|---|
| SA | 57.11±19.98 | 56.81±23.40 | 12.98±7.52*ϕ | 61.10±25.12 |
| UT | 41.10±14.60 | 42.10±13.49 | 13.59±12.89*ϕ | 12.58±6.31*ϕ |
| MT | 15.10±6.21 | 49.60±13.89# | 34.57±11.94*ϕ | 12.21±6.16 ϕ |
| LT | 12.76±6.15 | 10.70±5.07 | 44.20±18.42*ϕ | 8.20±3.75 |

Table1. Scapular Muscle average EMG activity during each exercise. Data reported as average %MVIC ± standard deviation. * indicates significant differences between single plane exercises (row/push up plus) versus the PNF D1 diagonal (P<0.05). ϕ indicates significant differences between single plane exercises versus the PNF D2 diagonal (P<0.05). # indicates significant differences between D1 and D2 (P<0.05).

*Muscle Ratios*

There were significant main effects for UT/LT ($P<0.0001$), UT/MT ($P=0.008$), and MT/LT ($P=0.001$) between the various exercises. Post hoc analysis revealed significantly higher UT/LT ratios for the D1 and D2 flexion exercises versus the throw ($P=0.005$ and $P<0.001$, respectively). D2 flexion elicited the highest UT/LT ratio versus the throw which demonstrated the lowest UT/LT activity (Figure 1). There was no significant difference between D1 and D2 for the UT/LT ratio ($P=0.54$).

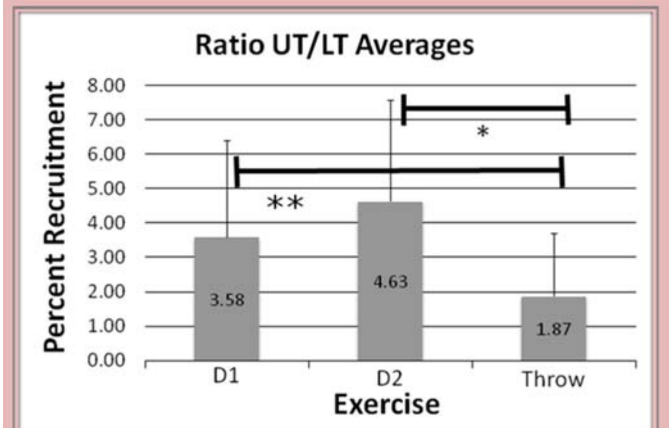


**Figure 1. Ratio of average EMG activity of upper trapezius to lower trapezius muscles during PNF exercises and overhead throw (Mean ± Standard Error). * P<0.01 and **P<0.05**

Post hoc analysis for UT/MT suggested significantly higher activity during D1 flexion versus throw ($P=0.02$). There was no significant difference in UT/MT activity during D2 ($P=0.34$) versus the throw or versus D1 ($p=0.45$) (Figure 2). Post hoc analysis for MT/LT showed significantly higher activity during D2 versus D1 ($P<0.001$) and during D2 versus throw ($P=0.031$). There were no significant differences in MT/LT activity between D1 and throw ($P=0.67$)( Figure 3).

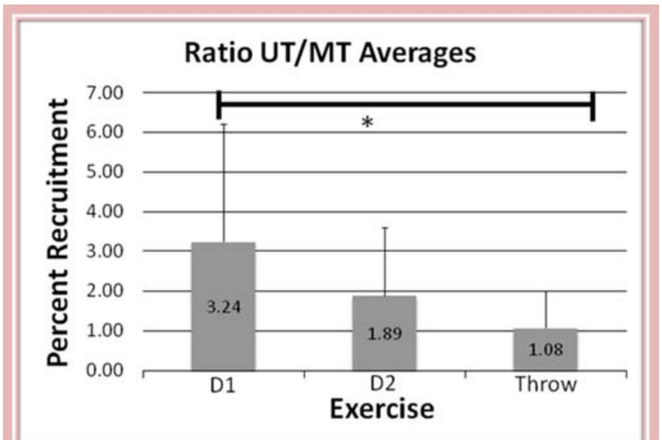


**Figure 2. Ratio of average EMG activity of upper trapezius to middle trapezius muscles during PNF exercises and the overhead throw (Mean ± Standard Error). * P<0.01 and **P<0.05**

**Discussion**

Scapular muscle training is an essential part of progressive shoulder rehabilitation and injury prevention exercise programs (Cools, 2007b). As the identification of the specific muscle recruitment patterns during an activity provide a scientific rationale for their use, various researchers have investigated the activation patterns of the shoulder muscles during different types of exercises. Although various exercises effectively recruit the scapular muscles, researchers have yet to suggest a single exercise that recruits muscles in a pattern similar to a common overhead activity such as throwing (Burkhart, 2003). Our study investigated the effects of PNF exercises on scapular muscle recruitment.

These findings support our primary hypothesis that performing PNF patterns will effectively recruit isolated muscles with the same intensity as exercises that target specific muscle function. However, contrary to our secondary hypothesis

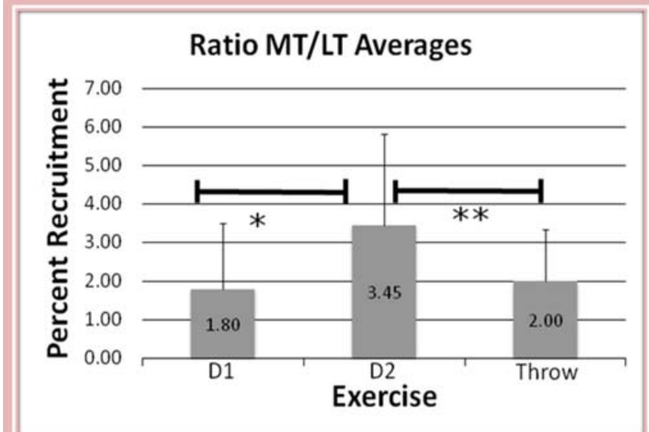


**Figure 3. Ratio of EMG activity of middle trapezius to lower trapezius muscles during PNF exercises and the overhead throw. (Mean ± Standard Error). * P<0.01 and **P<0.05**

these results suggest that performing PNF patterns does not result in similar activity ratios to those elicited by a functional activity such as an overhead throw. Previous research has shown comparable benefits of PNF patterns in regards to muscle recruitment and recruitment ratio changes (Padua et al., 2004). The results of this study might allow us to consider the use of PNF patterns as a recruitment regiment based on the significant activity levels found in multiple muscles. However, clinicians should not assume that the synergistic activity of the scapular muscles mimic that of an overhead functional activity.

When comparing the recruitment of the MT, these findings demonstrate that the D2 flexion pattern recruited greater MT activity compared to both the D1 pattern and the seated row exercise. This suggests that when attempting to target the

MT muscle, the D2 pattern will recruit more MT activity than doing a seated row or performing the D1 flexion pattern. In addition, the D2 pattern elicited significantly high SA activity. None of the other exercises were able to simultaneously recruit SA and MT at such significantly high magnitudes. This is an important finding because, in athletes with shoulder impingent, one of the primary rehabilitations goals is often to improve MT and SA recruitment. Cools et al.(2007b) supports this contention as they report that neuromuscular recruitment of these muscles may be diminished during shoulder impingement pathology, further indicating that scapular neuromuscular reeducation is an important aspect of treatment.

One of the important aspects of the incorporation of PNF into an orthopedic treatment program is the expected ability to reproduce similar recruitment patterns as that seen during a functional activity; i.e. throwing a ball for overhead athletes. Previous researchers have reported that muscle ratios are altered in patients with impingement syndrome (Cools et al., 2007a). In particular, the relationship between UT to LT (UT/LT) has been reported to be of particular importance. Our findings suggest UT/LT ratio was found to be significantly higher between D1 and the throw, and D2 and the throw. Previous research has shown that a lower ratio of UT/LT is desirable in rehabilitating impingement syndrome, but this higher ratio may have been due to low activity in the lower trapezius rather than over activity in the UT, which is the problem seen in athletes with impingement (Ekstrom et al., 2003). Cools et al.(2007a) found that the UT/LT ratio was the most significant ratio when comparing healthy shoulders to shoulders of athletes with impingement syndrome.

Although not all of the data in this study showed optimal muscle recruitment for impingement rehabilitation, it seems that PNF exercises may have some beneficial effects if monitored correctly. Further research must be done to determine if altering PNF patterns can decrease the ratios between trapezius recruitment, and still target the appropriate muscles. A previous study by Shimura and Kasai (2002) determined that just placing the upper extremity in a PNF position elicited greater motor evoked potential amplitude and decreased motor evoked potential latency during a wrist extension exercise. Therefore, exercises performed within a PNF position may help to recruit muscles more effectively, and if these exercises were performed in a limited range, or simply in an alternate position within the PNF range, the ratios may be closer to the desired value.

**Conclusion**

Previous research has shown discrepancies in muscle recruitment between healthy subjects and patients with shoulder impingement in scapular muscles. This study investigated recruitment quantity in straight plane exercises and PNF diagonal exercises in healthy subjects. PNF exercises demonstrated adequate recruitment in key muscles for impingement rehabilitation, but muscle ratios need to be monitored. Our findings suggest that PNF patterns might elicit too much UT activity for use in a pathologic population. However, further research must be conducted to determine if some form of PNF exercise should be utilized in the treatment of shoulder impingement in the overhead athlete.

**References**

Basmajian J, De Luca C (1985) *Muscles Alive*. Baltimore, MD. Williams and Wilkins.

Burkhart SS, Morgan CD, Kibler WB (2003) The disabled throwing shoulder: spectrum of pathology Part III: The SICK scapula, scapular dyskinesis, the kinetic chain, and rehabilitation. *Arthroscopy* 19:641-661.

Cools, AM, Declercq GA, Cambier DC, Mahieu N.N., Witvrouw EE (2007) Trapezius activity and intramuscular balance during isokinetic exercise in overhead athletes with impingement symptoms. *Scandinavian Journal Medicine Science Sports* 17:25-33.

Cools AM, Dewitte V, Lanszweert F, et al. (2007) Rehabilitation of scapular muscle balance: which exercises to prescribe. *American Journal of Sports Medicine* 35:1744-1751.

Cools AM, Witvrouw EE, Mahieu NN, Danneels LA (2005) Isokinetic scapular muscle performance in overhead athletes with and without impingement symptoms. *Journal of Athletic Training* 40:104-110.

Ekstrom RA, Donatelli RA, Soderberg GL (2003) Surface electromyographic analysis of exercises for the trapezius and serratus anterior muscles. *Journal Orthopedic Sports Physical Therapy* 33:247-258.

Inman VT, Saunders JB, Abbott LC (1996) Observations of the function of the shoulder joint. *Clinical Orthopedics* 330:3-12.

Kisner C and Colby LA (2002) Therapeutic Exercise: *Foundations and Techniques*. 4th ed. Philadephia, PA: F.A. Davis Company.

Ludewig PM, Cook TM (2000) Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. *Physical Therapy* 80:276-291.

Ludewig PM, Hoff MS, Osowski EE, Meschke SA, Rundquist PJ (2004) Relative balance of serratus anterior and upper trapezius muscle activity during push-up exercises. *American Journal Sports Medicine* 32:484-493.

Meislin RJ, Sperling JW, Stitik TP (2005) Persistent shoulder pain: epidemiology, pathophysiology, and diagnosis. *American Journal Orthopedics* 34:5-9.

Moseley J, Jobe F, Pink M, Perry J, Tibone J (1992) EMG analysis of the scapular muscles during a shoulder rehabilitation program. *American Journal of Sports Medicine* 20:128-134.

Padua DA, Guskiewicz KM, Prentice WE, Schneider RE, Shields EW. (2004). The effect of select shoulder exercises on strength, active angle reproduction, single-arm balance, and functional performance. *Journal Sports Rehabilitation* 13:75-95.

Shimura K, and Kasai T (2002) Effects of proprioceptive neuromuscular facilitation on the initiation of voluntary movement and motor evoked potentials in upper limb muscles. *Human Movement Science* 21:101-113.

Terry GC, Chopp TM (2000) Functional anatomy of the shoulder. *Journal Athletic Training* 35(3):248-255.

Urwin M, Symmons D, Allison T, et al. (1998) Estimating the burden of musculoskeletal disorders in the community: the comparative prevalence of symptoms at different anatomical sites, and the relation to social deprivation. *Annals Rheumatic Diseases* 57(11):649-655.

Van Der Windt DA, Koes BW, Boeke JP, De Jong BA, Bouter LM (1996) Shoulder disorders in general practice: prognostic indicators of outcome. *British Journal General Practice* 46:519-523.

Journal of Sports Therapy

**Reviews and invited commentary**

# Understanding the causes, prevention and treatment of osteoporosis (part 2): detecting and diagnosing the disease

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**KEY WORDS**

Osteoporosis
Bone mineral density
Densitometry
DEXA
DXA
Radiation

**ABSTRACT**

Osteoporosis is a multifactorial disease characterised by low bone mineral density (BMD), a disruption of the normal bone architecture, and increased risk of fracture. Common sites of osteoporotic fracture include the spine, hip, and forearm, with 1,150 people reportedly dying each month in the UK as a result of hip fracture. Worldwide the incidence of hip fractures is expected to more than triple from 1.66 million in 1990 to 6.26 million in 2050, while in the European Union an increase from 414 000 to 972 000 cases per annum is expected over the next 50 years. Osteoporosis is diagnosed clinically as a BMD of 2.5 standard deviations (SD) or more below the average for the young healthy female population. Therefore, BMD measurement is fundamental in assessing osteoporosis risk; comparable to measuring blood pressure to predict stroke and substantially better than measuring serum cholesterol to predict cardiovascular disease respectively. BMD is most commonly measured, at the hip or lumbar spine, using dual-energy x-ray absorptiometry (DXA). Measurements at other sites (primarily the heel and finger) using peripheral DXA or ultrasound is also possible, although not considered as accurate. Recently, other methods of analysis have become available, including micro- computed tomography (microCT) and quantitative computed tomography (QCT), which are able to better distinguish between trabecular and cortical bone. However, DXA is currently considered the gold standard for BMD measurement as it is accurate, precise, requires only a short scanning period, and has a limited radiation dose. The purpose of this article (the second of a four-part feature) is to define osteoporosis and its parameters, discuss the devastating impact is has on individuals and society, and explain the diagnostic methods used to quantify bone density.

Although believed to have been first described by French pathologist Lobstein in the 1820s, the negative impact of osteoporosis on the health of the ageing population has attracted serious attention in the clinical community in recent decades, with the magnitude of the problem now being fully appreciated. Officially recognised in 1994 by the World Health Organisation (WHO), with what is now the internationally accepted definition, osteoporosis is "a systemic disease characterised by low bone mass and micro-architectural deterioration of bone fragility and a consequent increase in fracture risk" (WHO, 1994). Osteoporosis literally means 'porous bone' and the disruption of the normal bone architecture, primarily caused by increased or uneven bone remodelling (see Hawkey, 2011; Journal of Sports Therapy 4, 1: 7), and is clearly visible in scans of healthy and diseased bone (Figure 1). While healthy, dense bone is strong and heavy, porous bone is similar to a hard, dried-out sponge (Figure 2). The subsequent reduction in bone strength leads to a much greater risk of bone fractures, even under small amounts of stress. Osteoporosis disrupts the trabecular structure, which results in reduced connectivity and integrity, ultimately increasing bone fragility and fracture risk. Common sites of osteoporotic fracture include, but are not limited to, the spine, hip, and forearm. Wherever the site of fracture though, bone pain and fragility often impact on an individual's quality of life, with the National Institutes of Health (NIH) describing the disease as devastating with significant physical, psychosocial and financial consequences (NIH, 2001). Hip fractures are the most serious type of osteoporotic fracture though, as they are especially disabling and can even cause premature mortality, with the NOS reporting that 1,150 people die in the UK each month as a result of hip fracture (NOS, 2010). To put this into perspective, the risk of a woman suffering a hip fracture is greater than the risk of developing breast cancer (Pountney, 2007), and approximately 20% of those who break a hip (estimated to be 70,000 in the UK alone) will eventually die as a result of their fracture (Stone, 2007). Also of concern is the statistic that of those who sustain a hip fracture only 40% of individuals will ever walk properly again (Stone, 2007). Approximately 50,000 hip replacements are performed every year in the UK and 193,000 in the US. Forty million Americans are estimated to have osteoporosis or osteopenia with a subsequent increased risk of hip fracture and the disease has an estimated cost to the US economy of $33.5 billion every year. The cost of each hip fracture in the UK is estimated to be over £12,000, with some stating this is as high as £24,000 when aftercare is also factored in (Sutcliffe, 2007). Hip fractures made up the majority of the cost of health and social care on osteoporosis treatment in 2000, which approached £1.8 billion. Sutcliffe (2007) estimates that this cost will increase to £2.1 billion in the very near future. Worldwide the incidence of hip fractures is expected to more than triple from 1.66 million in 1990 to 6.26 million in 2050, while in the European Union an increase from 414,000 to 972,000 cases per annum is expected over the next 50 years (Kanis, 2002), representing both a huge personal and social cost.

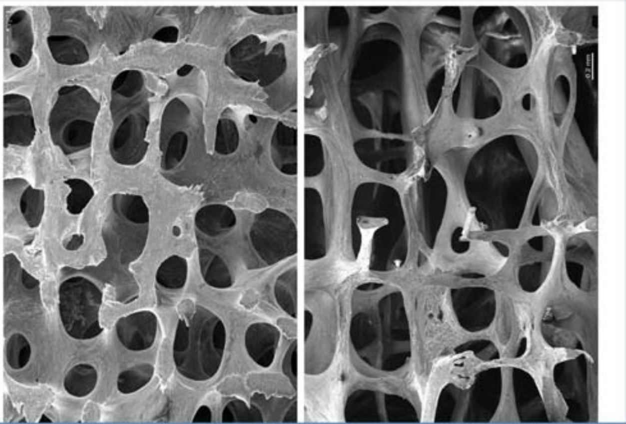


Figure 1. Comparison of normal (left) and osteoporotic bone architecture (right) of the 3rd lumbar vertebrae (used with permission of Tim Arnett)

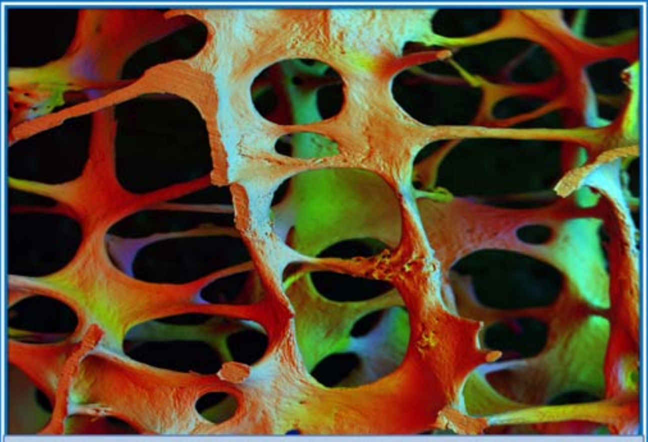


Figure 2. Microscopic scan of osteoporotic bone, highlighting significant deterioration, thinning, and pitting of trabecular structure (used with permission of Alan Boyde)

**Detecting and diagnosing osteoporosis**

Historically, measurement of bone mineral density (BMD) has been viewed as critical to the early detection of osteoporosis and it would appear that the lower the BMD, the higher the risk of fracture, regardless of measurement site. It has been reported that for each standard deviation decrease in BMD, fracture risk increases by approximately 200-300% (Anderson & Delmas, 2002). The importance of BMD measurement in assessing osteoporosis risk is comparable to measuring blood pressure to predict stroke and substantially better than measuring serum cholesterol to predict cardiovascular disease, respectively (Hui et al., 1998; Anderson and Delmas, 2002). The most commonly used method of determining BMD is from the bone mineral content (BMC); as bone mass is very highly correlated to its mineral composition (see Hawkey, 2011 – JST 4(1)). By dividing the BMC (g) by the area of bone being measured (cm2) a value of BMD (g/cm2) can be obtained. This is not a density in the traditional/engineering sense, that is, total mass divided by volume (g/cm3), but instead an areal density of mineral, sometimes referred to as aBMD. While early observations of BMD were based on the use of densitometry of plain x-rays (now considered an inaccurate technique), clinical diagnosis of osteoporosis is currently based on BMD measurement of the hip, and/or lumbar spine, using Dual Energy X-ray Absorptiometry (DEXA, now commonly referred to as DXA: Figure 3). Developed in the late 1980s, DXA is now widely available and is the established method for diagnosing osteoporosis, non-invasively, and for monitoring treatment outcomes (Miller et al., 1996; Williams and Daymond, 2003), with the Osteoporosis Working Group of the South African Medical Association (2000), stating that it is capable of measuring bone mass accurately (i.e the reliability of the measurement) (4-8% error) and precisely (i.e. targeting the desired site) (1-3% error). DXA works by differentiating the absorption of X-rays from two different energies, enabling the determination of the amount of mineral in a designated area. DXA is also able to measure the depth and composition of adjacent soft tissue to establish levels of lean and fat mass; this is important as overlying depths of fat, water, and air, and the thickness and composition of tissue surrounding the bone will have an effect on measured BMD (Laskey and Prentice, 1999). Conventional practice is to scan the hip and lumbar spine, as these areas provide the best available indicator of fracture risk at the same site (Marshall et al., 1996). The site of measurement, according to Bianchi (2002), maybe important as certain cases of osteoporosis, such as steroid-induced bone loss, which primarily affect trabecular bone; therefore more easily detected at the lumbar spine, due to the different ratios of trabecular and cortical bone in different regions (Brandi, 2009; Hawkey, 2011). To enable effective osteoporosis diagnosis, values obtained from DXA techniques are compared to reference data prescribed by the WHO (Kanis and Gluer, 2000). According to the recommendations of the WHO working group, osteoporosis is defined, in white women (the subpopulation with the most available data), as a BMD of 2.5 standard deviations (SD) or more below the average for the young healthy female population (WHO, 1994). This same BMD value is being provisionally used for men, as data on BMD and fracture in men remain scarce. The WHO working group has recommended T-score cut-off values for hip and spine measurements (WHO, 1994): T-scores of 1.0 or greater are classified as normal with a low fracture risk; scores between 1.0 and -2-5 are classified as osteopenia and come with a moderate risk of fracture; while scores lower than -2.5 are classed as osteoporosis and carry a high risk of future fracture risk (Figure 4). Special considerations are involved in the use of DXA to assess bone mass in children. Specifically, comparing the bone mineral density of children to the reference data of adults (to calculate a T-score) will underestimate the BMD of children, because children have less bone mass than fully developed adults. This would lead to an over-diagnosis of osteopenia for children. To avoid an overestimation of bone mineral deficits, BMD scores are commonly compared to reference data for the same gender and age (by calculating a Z-score: Figure 4).

Measurements at other sites using X-ray or ultrasound systems are also possible. Peripheral instantaneous X-ray imaging (PIXI: Figure 5) is a small, portable and relatively inexpensive alternative to DXA screening at the hip and spine; primarily conducted at the heel, wrist, or finger. Values for the calcaneous (heel bone: Figure 6) using the PIXI system are slightly adapted from those of the hip and spine scores. T-scores of >-0.6 are considered to be in the normal range, with a value of 0 being the mean for a young adult population between the ages of 20-50. The value can also be expressed as a percentage of a normal score (with 0 equalling 100%). T-scores between -0.6 and -1.6 are regarded as osteopenia, with T-scores less than -1.6 being classified as osteoporosis (Figure 7). With the NOS (2002) stating that the average primary care trust (PCT) in the UK, serving a population of 100,000, would need to perform approximately 1000 scans per year (at a cost of ranging from £70 - £200 per scan), and the PIXI scanner costing between £10,000 – £15,000 (and each scan reportedly costing as little as £5 per patient (Lawrensen et al., 2006)), the PIXI appears to be an acceptable and practical alternative to DXA screening in the community . Several studies have compared devices for measuring BMD using peripheral DXA at the heel with axial measurements. Some have reported that calcaneal measurements discriminate reasonable well between groups of osteoporotic patients (Diessel et al., 2000; Fordham et al., 2000; Langton and Langton, 2000; Sweeney et al., 2002) and correlate fairly well with

**Figure 3. Assessment of bone mineral density (BMD) using Dual Energy X-ray Absorptiometry (DXA) (used with permission of GE Healthcare)**

**Figure 4. Example of bone mineral density (BMD) using Dual Energy X-ray Absorptiometry (DXA) (used with permission of Adam Hawkey)**

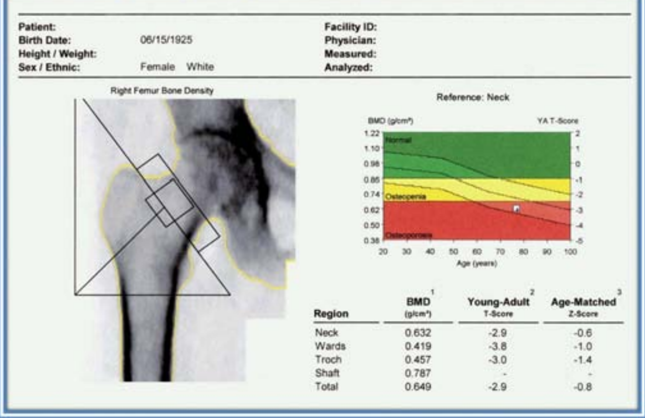
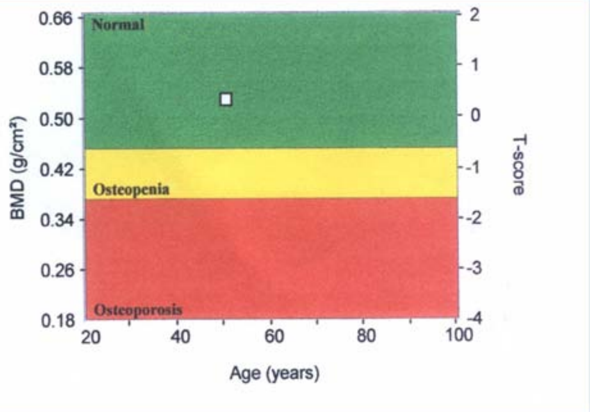



**Figure 5. Clinical assessment of calcaneal bone mineral density (BMD) with Peripheral Instantaneous X-ray Imager (PIXI) equipment (used with permission of Adam Hawkey)**

Figure 6. Area of calcaneous used for Bone Mineral Density (BMD) using Peripheral Instantaneous X-ray Imager (PIXI) (used with permission of Adam Hawkey)

Figure 7. Example scan of a Bone Mineral Density (BMD) assessment using Peripheral Instantaneous X-ray Imager (PIXI) (used with permission of Adam Hawkey)




measurements at axial sites (Salminen et al., 2005). However, some comparative studies have shown that it has only moderate comparability with DXA; in one such study, 23% of women who received an intermediate score on the PIXI were found to have osteoporosis of the hip and spine following DXA analysis (Lawrensen et al., 2006). One reason for these discrepancies could be because the heel is exposed to more force than other areas of the body; potentially leading to a BMD value that is not representative of the rest of the body (see Hawkey, 2011; Journal of Sports Therapy 4, 1: 6 for information on bone loading and remodelling).

In addition to obtaining differing readings from different anatomical sites, the type of DXA machine used can also affect BMD measurement. Three companies manufacture DXA machines (GE Healthcare, Horogic, and Norland). These machines are either pencil beam, which use a small angle beam of X-rays moving across the region in a rectilinear motion; or fan beam, which collect data using a wider angle beam. While scan duration using the fan beam is significantly reduced, radiation levels are increased (see information on radiation later in article). Recent advances (for example, those on the Lunar Prodigy and iDXA) now use a direct digital Cadmium Zinc Telluride (CZT), which reduces the magnification inherent to wide-angle fan beams to a minimum; allowing for faster scan times with lower radiation exposure (GE Healthcare, 2008a; 2008b). Magnification, machine calibration and edge detection are all issues that need to be addressed with regard to ensuring accurate measurements using the DXA system Fewtrell (2003). It is important to consider that if a patient is scanned using different machines on different occasions that discrepancies may arise. One reason for this is that GE Healthcare machines are calibrated to ashed bone while Horolgic machines use hydroxyapatite for calibration; leading to the former giving BMD readings approximately 16% higher (Fewtrell, 2003). As different DXA machines use different algorithms to detect the bone edge, there is also the possibility of over- or under-estimating bone mass. There is also the potential for error with patients of different size or 'thickness'; particularly relevant for scanning children (previously mentioned with regard to Z-scores), as machines are generally calibrated to the adult patient (Fewtrell, 2003). Also, there are other variables in addition to age that are suggested to confound the interpretation of BMD as measured by DXA. One important confounding variable is bone size. DXA has been shown to overestimate the bone mineral density of taller subjects and underestimate the bone mineral density of smaller subjects. This error is due to the way by which DXA calculates BMD. In DXA, bone mineral content (measured as the attenuation of the X-ray by the bones being scanned) is divided by the area (also measured by the machine) of the site being scanned. The confounding effect of differences in bone size is due to the missing depth value in the calculation of bone mineral density. Despite DXA technology's problems with estimating volume, it is still a fairly accurate measure of bone mineral content. Methods to correct for this shortcoming include the calculation of a volume that is approximated from the projected area measure by DXA. DXA BMD results adjusted in this manner are referred to as the bone mineral apparent density (BMAD) and are a ratio of the bone mineral content versus a cuboidal estimation of the volume of bone. Like the results for aBMD, BMAD results do not accurately represent true bone mineral density, since they use approximations of the bone's volume. BMAD is used primarily for research purposes and is not generally applied in clinical practice.

While bone densitometry measures have long been the standard technique to assess bone health and provide information regarding osteoporotic fracture risk, clinical research has indicated that BMD may only partly explain bone strength and highlights limitations when quantifying fracture risk and assessing any changes or responses to a variety of therapies (Bouxsein, 2008; Brandi, 2009). DXA is limited to areal measurements of BMD, which has been described as problematic to elucidate the effects of bone physical size and special variations in remodelling zones, such as cortical and trabecular bone (MacNeil and Boyd, 2007). There is increasing evidence that other factors such as bone architecture, turnover, damage accumulation, and mineralisation – termed in combination as bone quality – play an important role in assessing the risk of fracture (MacNeil and Boyd, 2006; Muller, 2002). Bone macrostructure can be quantitatively assessed by DXA and computed tomography (CT), in particular volumetric quantitative computed tomography (vQCT). The microstructure of trabecular bone can be assessed using high resolution CT (hrCT), micro CT, high resolution magnetic resonance (hrMR), and micro MR. Other techniques such as quantitative computed tomography (QCT) and microCT offer more detailed three-dimensional measurement of bone health (Thomsen, 2005), with Zanchetta et al (2003) stating that these volumetric assessments of BMD (vBMD; g/cm3) enables distinguishing between the aforementioned trabecular and cortical compartments. Genent et al (2008) explain that vQCT, hrCt and hrMR are generally used for in vivo analysis, while micro CT and micro MR and primarily applied to in vitro investigations. Kalpakcioglu et al (2008) state that investigating bone fragility, defining skeletal responses to innovative therapies, and assessing biomechanical alterations have all been advanced using these sophisticated imaging techniques. Brandi (2009) reports that while separate analysis of the trabecular and cortical components is afforded using QCT, the analysis of cortical bone is of particular importance to fracture risk estimations; evidenced from its utilisation in several clinical trials (Black et al., 2003; 2005). Peripheral QCT is also useful, providing a three-dimensional assessment of the structure and geometric properties of the appendicular skeleton with lower radiation exposure (Fewtrell, 2003). However, despite these emerging technologies, the use of DXA, and its ability to quantify BMD, is still the most commonly used method of assessing bone health and still widely accepted by medical professionals. Despite the differences in dimensionality, the areal BMD of DXA has been shown to correlate well (R2 = 0.69) with volumetric BMD, as assessed by HR-pQCT, improving to R2 = 0.69 when non-dimensional BMC was assessed (MacNeil and Boyd, 2007). One advantage of DXA over other technologies is the relatively low radiation dose it emits. While radiation is all around us, naturally present in the air we breathe, the food we eat, the water we drink, and in the construction materials used to build our homes, exposure to excessive amounts can be seriously damaging to our health, even fatal (United States Nuclear Regulatory Commission (USNRC), 2011). The relative radiation exposure risk from DXA is very low, with values approximating 0.02 - 5 microsieverts (µSv) for the whole body and 0.4 - 4 µSv for the lumbar spine; this compares to 5 - 30 µSv for dental X-rays (Brenner and Hall, 2007), 12 - 20 µSv for

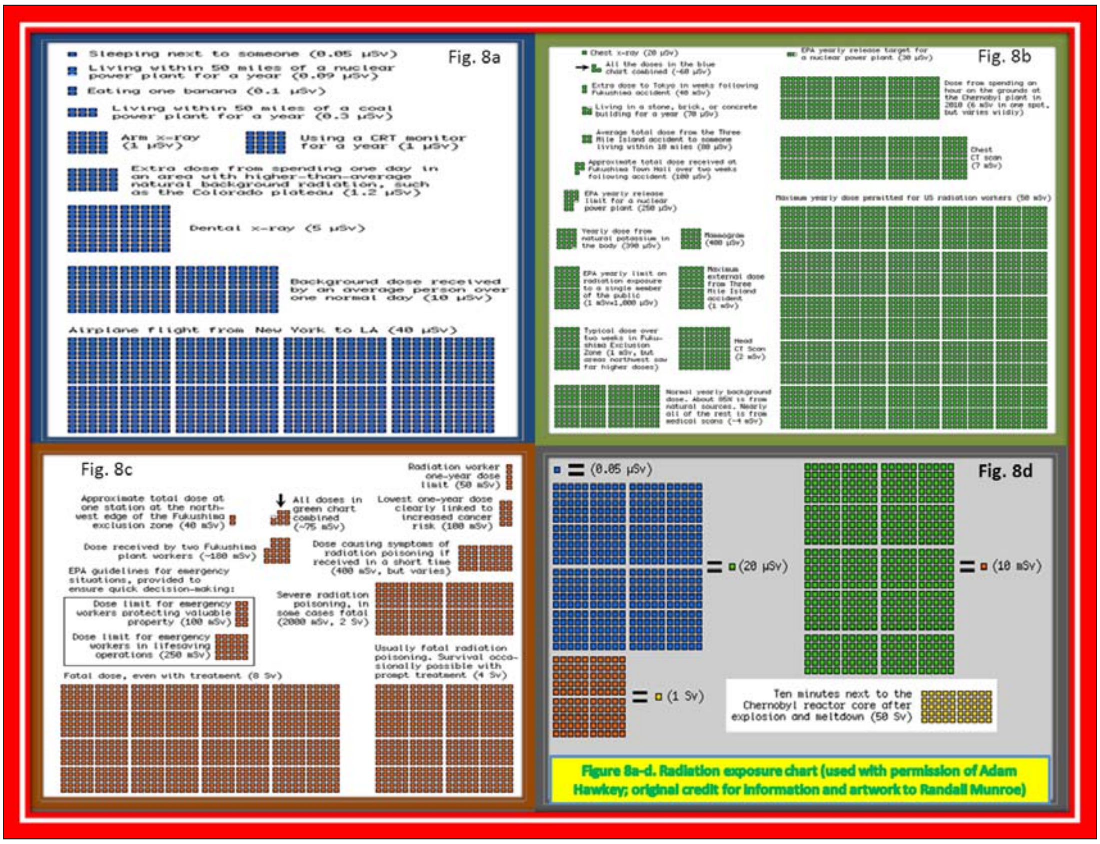


**Figure 8a-d. Radiation exposure chart (used with permission of Adam Hawkey; original credit for information and artwork to Randall Munroe)**

a chest x-ray and 80 µSv for a transatlantic return flight (Fewtrell, 2003). To put this into an everyday perspective, the amount of background radiation received in an average day in the UK is 10 µSv, while eating approximately three bananas is reported to register at 0.3 µSv; equivalent to some DXA measurements (Figure 8). CT scans of the brain (0.8 - 5 mSv) and the chest (6 - 18 mSv) expose the patient to much greater radiation levels (Van Unnik et al., 1997) and are therefore not routinely used for analysis. According to Conradie (2003), a single screening test for BMD is recommended, which should be accurate, require a short scanning period, have the ability to predict fracture risk and have a relatively low radiation dose. These criteria are currently best met by DXA; indicative of the fact that DXA is currently the most commonly used diagnostic method/technique, with many referring to it as the 'gold standard' for the clinical assessment of fracture risk (Cummings et al., 1995; MacNeil and Boyd, 2007).

Osteoporosis is a multifactorial disease characterised by low bone mineral density (BMD), a disruption of the normal bone architecture, and increased risk of fracture. It is a devastating disease with significant physical, psychosocial and financial consequences. With shocking statistics, such as 1,150 people dying in the UK each month as a result of hip fracture, and women being more at risk of suffering a hip fracture than that of developing breast cancer, the effective diagnosis, prevention, and treatment of osteoporosis, becomes a public health priority. It would appear that the measurement of BMD, through the gold standard of DXA, is crucial in the reduction, if not negation, of this disease. However, identifying those suffering from the disease is one thing, identifying those at greater risk (through genetic disposition or lifestyle choices) is another matter. Therefore, in the third instalment of this four part feature, the major risk factors for reducing BMD and causing osteoporosis will be discussed as will the lifestyle modifications we can make to improve our bone health throughout the course of our lives.

**References**


Anderson, M., and Delmas, P.D. (2002). Osteoporosis: an underdiagnosed and undertreated public health issue. *Karger Gazette,* 65: 3-5.

Bianchi, M.L. (2002). Glucocorticoids and bone: some general remarks and some special observations in pediatric patients. *Calcified Tissue International,* 70: 384-90.

Black, D.M., Greenspan, S.L., Ensrud, K.E. et al. (2003). The effects of parathyroid hormone and alendronate alone or in combination in postmenopausal osteoporosis. *New England Journal of Medicine,* 349: 1207-15.

Black, D.M., Bilezikian, J.P., Ensrud, K.E. et al. (2005). One year of alendronate after one year of parathyroid hormone (1-84) for osteoporosis. *New England Journal of Medicine,* 353:555-65.

Bouxsein, M.L. (2008). Technology insight: non-invasive assessment of bone strength in osteoporosis. *Nature Clinical Practice Rheumatology,* 4: 310-18.

Brandi, M.L. (2009). Microarchitecture, the key to bone quality. *Rheumatology,* 48: 3-8.

Brenner, David J.; Hall, Eric J. (2007). Computed Tomography — an Increasing Source of Radiation Exposure. *New England Journal of Medicine* 357(22): 2277–84.

Conradie, M.M. (2003). Technology in bone densitometry. CME, 21(4): 224-6.

Cummings, S.R., Nevitt, M.C., Browner, W.S., Stone, K., Fox, K.M., Ensrud, K.E. et al. (1995). Risk factors for hip fracture in white women. Study of Osteoporotic Fractures Research Group. *New England Journal of Medicine,* 332(12): 767-73.

Diessel, E., Fuerst, T., Njeh, C.F., Hans, D., Cheng, S., Genent, H.K. (2000). Comparison of an imaging heel quantitative ultrasound device (DTU-one) with densitometric and ultrasonic measurements. *The British Journal of Radiology,* 73: 23-30.

Fordham, J.N., Chinn, D.J., and Kumar, N. (2000). Identification of women with reduced bone density at the lumbar spine and femoral neck using BMD at the os calsis. *Osteoporosis International,* 11: 797-802.

Fewtrell, M.S. (2003). Bone densitometry in children assessed by dual x-ray absorptiometry: uses and pitfalls. *Archives of Disease in Childhood,* 88: 795-798.

GE Healthcare. (2008a). *Lunar Prodigy Advance: Innovation and dedication*. General Electric Company: Madison, WI.

GE Healthcare. (2008b). *Innovation and dedication: Osteoporosis management*. General Electric Company: Madison, WI.

Genent, H.K., Engelke, K., and Prevhal., S. (2008). Advanced CT bone imaging in osteoporosis. *Rheumatology*, 47(Suppl. 4): iv9-16.

Hawkey, A. (2011). Understanding the causes, prevention and treatment of osteoporosis (part 1): the structure of bone and the remodelling process. *Journal of Sports Therapy*, 4(1): 2-9.

Hui, S.L., Slemenda, C.W. & Johnston, C.C. (1998). Age and bone mass as predictors of fracture in a prospective study. *Journal of Clinical Investigation*, 81: 1804-1809.

Kanis, J.A. (2002). Diagnosis of osteoporosis and assessment of fracture risk. *Lancet,* 359: 1929-1936.

Kanis, J.A., and Gluer, C.C. (2000). An update on the diagnosis and assessment of osteoporosis with densitometry. Committee of Scientific Advisors, International Osteoporosis Foundation. *Osteoporosis International*, 11: 192-202.

Kalpakcioglu, B.B., Morshed, S., Engelke, K., and Genent, H.K. (2008). Advanced imaging of bone macrostructure and microstructure in bone fragility and fracture repair. *Journal of Bone and Joint Surgery America,* 90(Suppl. 1): 68-78.

Langton, C.M. and Langton, D.K. (2000). Comparison of bone mineral density and quantitative ultrasound of the calcaneus: site-matched correlation and discrimination of axial BMD status. *The British Journal of Radiology*, 73: 31-35.

Laskey, M.A. and Prentice, A. (1999). Comparison of adult and paediatric spine and whole body software for the Lunar dual-energy X-ray absorptiometer. *The British Journal of Radiology*, 72: 967-76.

Lawrensen, R., Nicholls, P., Rivers-Latham, R., Brown, T., Barnardo, J., and Gray, R. (2006). PIXI bone density screening for osteoporosis in postmenopausal women. *Maturitas*, 53: 245-251.

MacNeil, J.A. and Boyd, S.K. (2007). Accuracy of high-resolution peripheral quantitative computed tomography for measurement of bone quality. Medical Engineering & Physics, 29: 1096-1105.

Marshall, D., Johnell, O., and Wedel, H. (1996). Meta-analysis of how well measures of bone mineral density predict occurrence of osteoporotic fractures. *British Medical Journal*, 312: 1254-60.

Miller, P.D., Bonnick, S.L., and Rosen, C.J. (1996). Consensus of an international panel on the clinical utility of bone mass measurements in the detection of low bone mass in the adult population. *Calcified Tissue International*, 58: 207-14.

National Institutes of Health. (2001). Osteoporosis prevention, diagnosis, and therapy. *Journal of the American Medical Association,* 285: 785-795.

National Osteoporosis Society (2010). National Osteoporosis Society Annual Report 2010. Available at: http://www.nos.org.uk/document.doc?id=849.

Pountney, D. (2007). Osteoporosis. *Nursing Older People*, 19(3), 19-21.

Salminen, H., Sääf, M., Ringertz, H., and Strender, L.E. (2005). Bone mineral density measurement in the calcaneus with DXL: comparison with hip and spine measurements in a cross-sectional study of an elderly female population. *Osteoporosis International,* 16: 541-551.

Stone, D. (2007). Quoted in Pountney, D. Osteoporosis. *Nursing Older People,* 19(3), 19-21.

Sutcliffe, A. (2007). Quoted in Pountney, D. Osteoporosis. *Nursing Older People,* 19(3), 20-21.

Sweeney, A.T., Malabanan, A.O., Blake, M.A., Weinburg, J., Turner, A., Ray, P., and Holick, M.F. (2002). Bone mineral density assessment: comparison of dual-energy X-ray absorptiometry measurements at the calcaneus, spine, and hip. *Journal of Clinical Densitometry,* 5: 57-62.

Thomsen, J.S., Laib, A., Koller, B., Prohaska, S., Mosekilde, L.I., and Gowin, W. (2005). Stereological measures of trabecular bone structure: comparison of 3D micro computed tomography with 2D histological sections in human proximal tibial bone biopsies. *Journal of Microscopy,* 218: 171- 9.

United States Nuclear Regulatory Commission (USNRC). (2011). Fact Sheet on Biological Sources of Radiation. Available at: http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/bio-effects-radiation.html.

Van Unnik, J.G., Broerse, J.J., Geleijns, J., Jansen, J.T., Zoetelief, J., and Zweers, D. (1997). Survey of CT techniques and absorbed dose in various Dutch hospitals. *The British Journal of Radiology,* 70 (832): 367–71.

Williams, E.D. and Daymond, T.J. (2003). Evaluation of calcaneus bone densitometry against hip and spine for diagnosis of osteoporosis. *The British Journal of Radiology*, 76: 123-8

World Health Organisation (WHO). (1994). Study Group Report: Assessment of fracture risk and its application to screening for postmenopausal osteoporosis. *WHO Technical Report Series 843*. WHO: Geneva, Switzerland.

Zanchetta, J.R., Bogado, C.E., Ferretti, J.L., Wang, O., Wilson, M.G., Sato, M., et al (2003). Effects of teriparatide [recombinant human parathyroid hormone(1-34)] on cortical bone in postmenopausal women with osteoporosis. *Journal of Bone and Mineral Research,* 18(3): 539-43.

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**Reviews and invited commentary**

# Research Concepts and Methods (part 4)

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## INTRODUCTION

At the conclusion of the third part of this series, Research Concepts and Methods – 3, I pointed to the first of four combinations of research methodology constructs, that of quantitative outputs for analysis generated via statistical methods directly from quantitative data inputs. This article offers an overview of the nature and characteristics of this type of research, and also outlines some of the major considerations that need to be addressed before embarking on any data collection for such work. I am not attempting to describe or explain individual quantitative or statistical methods – there are myriad textbooks (see my short list of recommended texts below), available at all levels of study for these purposes – my aim here is to outline the main underpinning concepts relating to quantitative inputs and outputs; and, for convenience, and within the context of this, I also use the terms statistics and quantitative inputs and outputs interchangeably. With this in mind, I set out below the following sections: a closer examination of the statistical utility framework illustrated in the previous article (Research Concepts and Methods-3 Journal of Sports Therapy Vol. 3 Issue. 3); an introduction to the main parameters for testing hypotheses; the relationship between samples and populations; and some concluding remarks.

### The statistical utility framework

It is useful to think about the range of available basic statistical techniques as being organised into three groups or families of models each with its own generic purpose, but not ignoring that there are often degrees of overlap between them, and also sometimes analytical contingencies that bring together different elements from each of them. For example, the concept of the mean number in a normally-distributed survey sample allows for the separation of that distribution into standard deviations that, in turn, allow the probability estimations that are often central to making generalisations about populations from samples. Effectively, the mean and standard deviation are descriptive statistics, and generalisations from samples are inferential statistics. However, the real benefit accruing to the researcher from the statistical utility framework comes from the guidance it offers when designing methods frameworks. And, at this point I would stress the all-important difference between methods construction and methodology. Method constructions are designed before the research commences, in fact research processes cannot commence without them; whereas methodologies, being the a posteriori study of how the research techniques employed unfolded, must logically be constructed only when the research has been completed, and then arguably written retrospectively. Therefore, the utility framework is intended to assist the research design by delimiting certain types of outcomes, and allowing the researcher to make related decisions about the type of organised data that is required to factor into the models in order to generate these different outcomes. For example, there is little point in designing a questionnaire where the questions are set to generate responses which are couched in dichotomous or ordinal ranking terms, and then attempt to build a regression model from the resultant data; or, hope to construct an inferential model based on any data that are not continuous in nature. Equally important is the danger of employing overkill with generated data: if you only wish to show an average response or median position with a range of numerical data, straightforward descriptive use of statistics is not only adequate, but can often be much more effective in communication, and powerful in message, than obfuscating results, by, for example, in an attempt to unnecessarily correlate or regress subsets of the collected data. On the other hand, if, in the example above the researcher sets out to establish an overall mean statistic from the data, and also wants to contrast and compare say male and female responses against the overall mean, and with each other, or even male and female responses relative to age groupings, within each of these subsets, then t tests or analysis of variance tests using the same data may also be options. Again, to reinforce the point, the proposed analytical framework and associated choice of technique, must predetermine the type of data to be collected, and the statistical utility framework can therefore be employed as a departure point for methods construction in general, and raw data collection considerations in particular. *(Please see Research Concepts and Methods -2 in the Journal of Sports Therapy Vol. 2 Issue. 2).*

### Parameters for testing hypotheses

Once the decision has been made to employ either inferential or associative and predictive techniques for the analysis of organised data, there are two further considerations for the researcher: establishing a hypothesis together with a null hypothesis; and deciding on a suitable, and perhaps also acceptable, confidence level for the testing of results. In terms of the hypothesis and null hypothesis, researchers are more often than not looking either to substantiate a claim as basis from which further enquiries into the subject area can begin, or alternatively, establish some evidence which suggests that there is not enough evidence for pursuing the enquiry. The two types of hypotheses are formally known either as Ho for null hypothesis and Ha for alternative hypothesis, or sometimes with numerical subscripts respectively as H0 and H1. The generally-accepted language pertaining to these is either 'there is not enough statistical evidence to reject (or refute) the null hypothesis', which means there is not enough evidence to suggest a statistically significant 'difference', 'effect', 'movement' 'change in outcome' or some other noticeable behavioural shift within or between the data sets under review……; or there is enough statistically significant evidence to reject the null hypothesis and therefore there maybe evidence to support an alternative hypothesis. Note the use of the term 'significant' which is explained below, and also the conservative and cautious tone of the phrases.

With the hypotheses set out, the second initial consideration relates to confidence. And, in turn, any confidence level has an error counterpart, sometimes denoted as alpha (α). The easiest way of handling this aspect of statistical testing is to think of both components adding up to 100%. So, if is decided that a margin of error of up to 10% is acceptable in order to reject the null hypothesis, and therefore move forward with an alternative hypothesis, the confidence level would be automatically set at 90%, a margin of error of 5% would accompany a 95% confidence level, and if 99% is sought then the error margin would be 1% and so on. The error margin is always reflected in the majority of available statistical software packages[1] as a probability number, usually as a decimal fraction (0.10 for 10%, 0.05 for 5%, and 0.01 for 1%), and id denoted by 'p', so a p value expressed as $p < 0.05$ means that the probability of error in rejecting the null hypothesis is only accepted when the researcher is looking for 95% confidence in results obtained, by knowing that there is only a maximum 5% error, or probability, that the results could have been obtained by chance alone.

Of course, if the results show a 0.05001 p value, the researcher will have to make a subjective decision whether to accept this as enough evidence to reject the null hypothesis, and accept a confidence level of 94.999%, or not.

The setting of confidence levels is then always a matter of the researcher's judgment, and there will always be different demands made of the margin of error. For example, it may be perfectly acceptable for a sports therapist who is testing for a difference in performance between men and women on a given exercise, to accept a p value of up to 10% and therefore be happy with a 90% confidence level. On the other hand, the same researcher may wish to test the beneficial effects of a new treatment to a specific injury by performing a 'before and after 'paired t test, and would demand a much lower margin of error, say 1%, especially if the suggested treatment were to become generally accepted in practice.

Finally, in this section, it is important to return to the all-important term 'significant'. In statistics this does not mean important or worthy of note. It is usually accompanied by the word 'statistically', and when the term statistically significant is used, it is accepted that any 'observed effect is so large that it would rarely be occur by chance' (Moore, 2000:194). So, in order to reject any null hypothesis during testing, or use the null hypothesis to substantiate the existence of no difference between observed variables, then we seek statistically significant p values from our testing, at whichever level of confidence is deemed contextually appropriate.

The relationship between samples and populations

Statistics relate to samples, and parameters relate to populations. We use samples in order to make observations and offer generalisations about populations. Sometimes, we will not even know the size of the population, but as some statistical techniques are so powerful, we can still confidently make useful observations about some of its numerical characteristics. This is due to the power of sampling. There is much discussion and advice offered about this topic in most, if not all, the available text books, and as above it is not intention to offer any instruction or illustration as to the selection or justification of types or sizes of samples. However, I will offer two important and interrelated considerations: sample size and sample representativeness.

It is not uncommon for a student or an experienced researcher to find themselves confronted by the problem of sample size. This is usually the case after the decision has been made in terms of type of sampling ( convenience, stratified, cluster, random etc…). How many questionnaires are needed? How many observations? How many opinions? The problem is that although there are various formulas very clearly offered in many texts in order to calculate an appropriate sample size for a given population, they are often of little use. This because we may not know the size of the population, and if we do, many calculations based on the known parameter will often generate an impracticable number in relation to the time and other resources available to the researcher. A more manageable approach is to consider the potential margin of error of sample (this is different to the p or alpha values in statistical significance discussed above) you are prepared to accept, and then to plan to conduct repeated samples of a more manageable size. A good example of this can be taken from politics. Every five years or so in the United Kingdom (UK), we have a General Election to determine and elect a set of politicians, who are organised

[1]For example Minitab, Statistical Package for the Social Sciences (SPSS) and Microsoft Excel.

into political parties. The are nearly 45 million potential voters in the UK (45,000,000), and political analysts, television pundits, and whole range of other interested parties, who are keen to be able to forecast how many 'parliamentary seats' each party will win, and therefore predict which party will form the next government. You may be surprised to know that the professional pollsters (marketing statisticians), choose a sample size of just 3,000, or one for every fifteen thousand potential voters, and work with a sample margin of error of about 5%. Their results are surprisingly accurate, and there are two reasons for this: the use of standard error and the diminishing utility of increasing the sample size. The standard error (SE) is calculated by dividing the standard deviation of responses by the square root of the size of the sample ( $SE = sd/\sqrt{n}$ ).

The diminishing utility of increasing the sample is set out in the figure 1 below. Here randomobservations of a variable between 0 and 100 from an unknown population with a mean of 50 and two standard deviations, at a 95% confidence level. The salient point to note is that even major increases in sample size have relatively small impacts on acceptable spreads of observations. For example, in the table in Figure 1 below, notice that more than doubling the sample size from 400 to 900 moves the standard error from 0.75 to 0.50, but only achieves a 1% reduction in the accepted margin of error; from between 48.50 and 51.50 for the sample of 400, to between 49.00 and 51.00 for the sample of 900, So, by more than doubling the sample size, there is only a single digit reduction of the acceptable spread. With this in mind, it is often more useful to repeat smaller sample sizes, and then take a mean reading of the resultant means (even if the population is not known), than to aim for a much larger one-off sample size relative to a known population. This is because

Figure 1. Random observations between 0-100 when the population is unknown, assuming a mean of 50, and showing two levels of spread or standard deviation

| Tolerance accepted (standard error (SE)) | Sample size (n) | Sample mean | Sample standard deviation | Population mean estimate at 95%confidence level |
|---|---|---|---|---|
| 1.50 | 100 | 50.00 | 15.00 | 47.00 to 53.00 |
| 1.25 | 144 | 50.00 | 15.00 | 48.50 to 52.50 |
| 1.00 | 225 | 50.00 | 15.00 | 48.00 to 52.00 |
| 0.75 | 400 | 50.00 | 15.00 | 48.50 to 51.50 |
| 0.50 | 900 | 50.00 | 15.00 | 49.00 to 51.00 |
| 1.50 | 25 | 50.00 | 7.50 | 47.00 to 53.00 |
| 1.25 | 36 | 50.00 | 7.50 | 47.50 to 52.50 |
| 1.00 | 57 | 50.00 | 7.50 | 48.00 to 52.00 |
| 0.75 | 100 | 50.00 | 7.50 | 48.50 to 51.50 |
| 0.50 | 225 | 50.00 | 7.50 | 49.00 to 51.00 |

repeated sample means will more ever closer to population mean, even if that mean is not known!

In terms of representativeness, we are again presented with a problem, this time in the form of a paradox, which is nicely described by Derek Rowntree, and as quoted in the second article of this series

> The problem has been called the 'paradox of sampling'. A sample is misleading because unless it is representative of the population; but how can we tell it is representative unless we *already* know what we need to know about the population, and therefore have no need of samples? (Rowntree, 1991:23) (Italic emphasis added)

The answer is that there is no answer to the paradox, other than to consider statistical alternatives, such as the standard error - repeated sample method described above.

**Concluding remarks**

I have attempted here only to have alerted the sports therapist researcher to some of the central features which contribute to the nature and characteristics of quantitative input-quantitative output analysis. It is up to individuals to make up their own minds as to which models and techniques to employ in their research, but in doing so they will always be charged with the methodological responsibility of explaining and justifying their choice of statistical modelling and analysis. I hope that some of the foregoing commentary will at least assist in this very important task.

In the next part of the series I will examine some of the main features and problems associate with quantitative input and qualitative output modelling

**References**

Moore, D.S. (2000) *The Basic Practice of Statistics*, (second edition), New York: W.H.Freeman

Rowntree, D. (1991) *Statistics Without Tears*, London: Penguin

**Recommended texts for quantitative inputs with quantitative outputs**

Agresti, A. and Finlay, B. (1997) *Statistical Methods for the Social Sciences* (3rd edition), New Jersey: Prentice-Hall

Cramer, D. (1997) *Basic Statistics for Social Research: step-by-step calculations and computer techniques using Minitab*, London:Routledge

Friend, D. (1987) *Quantitative Methods*, New York: Longman

Moore, D.S. (2000) *The Basic Practice of Statistics*, (2ndedition). New York: Freeman

Rowntree, D. (1991) *Statistics Without Tears*, London: Penguin

Swift, Land Piff , S. (2005) *Quantitative methods for business management and finance*, Basingstoke: Palgrave Macmillan

http://jst.ucb.ac.uk Volume 5. Issue 1. Journal of Sports Therapy

**Original research**

# The characteristics of professional and semi- professional football players following off-season and pre-season training periods

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**KEY WORDS**

Football.
Off-season.
Pre-season training.
Fitness testing.
Professional.
Semi-professional.

**ABSTRACT**

The current was a within and between group repeated measures comparison of the performance of professional and semi-professional football players following off-season and pre-season training periods on a battery of fitness tests. Following ethical approval, 23 professional and 16 semi-professional male football players completed informed consent and medical questionnaires. Participants completed two testing sessions, immediately following the off-season and 6-week pre-season training periods. A mixed design group (playing level) by time MANOVA indicated an effect for differences in performance over time (Wilks lambda 7,28 = .20, P < .01, Partial Eta2 = .90) and an interaction effect for differences in performance over time by playing level (Wilks lambda 7,28 = .20, P < .01, Partial Eta2 = .80). Univariate follow-up tests indicated effects for differences over time in body fat (F 1,44 = 54.62, P < 0.01, Partial Eta2 = .62), 15m sprint time (F 1,44 = 67.96, P < 0.01, Partial Eta2 = .67), anaerobic endurance (F 1,44 = 18.17, P < 0.01, Partial Eta2 = .35), and the YIET (F 1,44 = 46.98, P < 0.01, Partial Eta2 = .58). Interaction effects were indicated for differences in body fat (F 1,44 = 25.78, P < .01, Partial Eta2 = .43), 15m sprint time (F 1,44 = 71.36, P < .01, Partial Eta2 = .68), anaerobic endurance (F 1,44 = 5.32, P = .03, Partial Eta2 = .14), and agility (F 1,44 = 5.78, P = .02, Partial Eta2 = .15), over time by playing level. With the exception of 15m sprint time, all interaction effects were due to the greater improvements over time of the semi-professional players. Pre-season training programmes may lack sufficient specificity to illicit adaptations in certain key fitness components. Consequently, football players may be commencing the playing season without the necessary levels of conditioning.

## Introduction

Football can be classified as an aerobic or endurance sport encompassing short periods of intense anaerobic activity throughout the ninety minutes of a game (Svensson & Drust, 2005). Professional outfield players cover distances of 9 – 14 km and make 1000 – 1400 changes of direction during the course of a game (Bangsbo, 2003; Mohr et al., 2003). The majority (85%) of a game involves low intensity activity (60% walking, 25% jogging), 10% of a game involves high intensity activity (6.5% running, 2.0% high speed running and 0.5% sprinting), whilst approximately 5% of time is spent standing still (Bradley et al., 2009). The duration of each sprint tends to be short, with approximately 50% of sprints being shorter than 10m and approximately 95% of sprints being less than 30m (Stolen et al., 2005). Although the majority of game time is spent in low intensity activity, it is the high intensity activity that occurs at crucial times during the game (Carvalho, 2004). Due to these varied physiological demands, football players require high levels of aerobic and anaerobic endurance, speed and agility (Reilly, 1996). Low levels of body fat may also be beneficial to football performance (Ostojic, 2003). Improvements in these fitness components have been shown to improve football performance in relation to distances covered during a game, level of work rate intensity, number of sprints and the degree of involvement with the ball during the game (Helgerud et al., 2001).

The characteristics of football players have been shown to differ depending on their playing level. For example, elite players may demonstrate significantly greater VO2max values in comparison with non-elite players (Metaxas et al., 2000), and this results in elite players covering greater distances at a greater intensity during match play (Mohr et al., 2003). This ability to cover a greater distance at a higher intensity may be the most notable difference between elite and non-elite players. International level players have been reported to cover a 28% greater distance in high intensity running than lower level professionals (2.43km and 1.9km respectively) and a 58 % greater distance sprinting (650m and 410m respectively) (Mohr et al., 2003). It has also been suggested that agility is an important factor in differentiating between elite and non-elite players (Gil et al., 2007).

Whilst the physiological preparation of football players aims to maintain an optimal level of fitness over the course of a season, fluctuations in both volume and intensity of training can impact on fitness and performance (Bangsbo, 2003). During the competitive season games are played on average twice a week and training focuses primarily on speed, tactical and technical improvements (Bangsbo, 1996). The consequent lack of general conditioning training may lead to significant reductions in fitness levels towards the end of the season (Mohr et al, 2005; Casajus 2001; & Roi et al, 1993). The competitive season is followed by an off-season period that lasts approximately eight weeks and acts as a players holiday period with no organised club training or matches. This abrupt interruption of training and the resulting passive rest has been found to lead to detraining and a loss fitness gained from the previous 10 months hard work (Aziz et al, 2002). Following the off-season period there is an intense 5 – 7 week period of pre-season training which forms the basis for the conditioning of the professional and semi-professional football player (Reilly, 1990). The pre-season training phase is crucial to the entire training year as it is used to develop the general framework of physical conditioning for the competitive season (Bangsbo, 2003). The pre-season period may be broken down into two phases; general and specific. The general phase involves high training volumes in order to develop aerobic endurance, and the commencement of strength training programmes to facilitate future explosive (sprint & agility) work. The specific phase represents a transition towards the competitive season as training becomes more specific to match play (Bompa, 1999). This transition involves a shift towards more high intensity aerobic exercise, speed, speed endurance training and friendly matches (Bangsbo, 1996).

There is contradictory evidence relating to the effectiveness of pre-season training. Significant improvements in VO2max have been reported following pre-season training, and this has been attributed to the emphasis placed on aerobic endurance exercises during this period (Bangsbo, 2003; Aziz et al., 2002) and the relatively low level of aerobic endurance of the players following the off-season period (Islegen and Akgun, 1988). Positive changes in body fat percentage following pre-season training have also been reported (Hoshikawa et al., 2005). Conversely, it has been suggested that the pre-season period is neither long nor specific enough to illicit the specifically required physiological adaptations (Rebelo and Soars, 1997). The emphasis placed on aerobic endurance exercises may result in a lack of improvement in fitness components such as anaerobic endurance, football specific intermittent endurance performance, and linear sprint performance. Greater improvements in these fitness components have been reported during the competitive season in comparison with pre-season, and this has been attributed to the relative lack of specificity of pre-season training (Aziz et al., 2002; Rebelo and Soars, 1997; Mercer et al., 1997). As a result, players may begin the competitive season without the levels of fitness required for maximal performance. More recently, football specific small-sided games have been found to be a useful training tool to elicit the required physiological adaptations for football performance. Small-sided games may provide the necessary training intensity in addition to the specificity that may otherwise be lacking in pre-season training, and may also improve the motivation of the players (Bangsbo, 2003; Hoff et al., 2002; McMillan et al., 2005). Maximal heart rates of approximately 90% have been reported when using both 4 v 4 and 8 v 8 small-sided games, and this compares favourably with the heart rate response to more traditional 4 x 1000m interval runs with a 2.5 minute recovery between each run Sassi et al. (2004). This level of training intensity is in line with the range of 80 – 90 % of maximal heart rate recommended by Bangsbo (2003) for the improvement of aerobic capacity in football players. Whilst small-sided games may therefore be useful, small changes in the way the games are structured, for example the size of the pitch, number of players, duration of the game, and the rules used, can significantly alter the training stimulus provided (Aroso et al., 2004).

The importance of assessing the physical characteristics of football players following the off-season and pre-season periods has been highlighted Bangsbo (2003), and this has traditionally been achieved through the administration of a battery of fitness tests. A test battery must contain tests that reflect the demands of the sport (Gratton & Jones, 2004), and wide a range of tests to assess the key fitness components of aerobic and anaerobic endurance, speed and agility have been reported in the football literature. In terms of aerobic endurance, the Yo-Yo Intermittent Endurance Test (YIET) has been frequently used as it simulates the intermittent nature of game play (Barnes, 2007). It may also be a more suitable method of assessing football players' intermittent endurance than both measured VO2max values and performance on the continuous 20-m multistage shuttle run test (Aziz et al., 2002). The YIET has also been found to be a sensitive measure of physiological adaptation and has the ability to discriminate between playing standards (Bangsbo & Michalsik, 2002). The sprint speed and anaerobic endurance of football players are frequently assessed using single sprint and repeated sprint protocols respectively, and many of these protocols have been found to be reliable, valid and able to differentiate between different playing levels (Wragg, 2000; Dunbar and Treasure, 2005). Results from repeated sprint tests may be presented as fatigue index calculated by subtracting the fastest sprint time from the slowest time. A high fatigue index suggests a poor ability to recover between sprints and an inability to replenish phosphocreatine stores and remove blood lactate between each sprint (Tomlin & Wenger, 2001). A low fatigue index is therefore more beneficial as it suggests the ability to recover between high intensity exercise bouts. The tests used to assess the agility of football ball players can be split in to two distinct categories; tests of change of direction speed (CODS), and tests which also incorporate perceptual/decision making factors (Gabbett, Kelly and Sheppard, 2008; Young, James and Montgomery, 2002). CODS can be considered a player's physical capacity to complete a planned movement requiring at least one change of direction, whereas perceptual skill in this context involves the payer's ability to interpret and react to a stimulus and make at least one change of direction (Farrow, Young and Bruce, 2005). One CODS test that has been found to be reliable, valid, and able to differentiate players of different standards is the 'Arrow Agility Test' (Smith & Galloway, 2007). The aim of this study was to compare the characteristics of professional and semi-professional football players following off-season and preseason training periods.

## Methods

### Participants

Thirty nine (n=39) male football players volunteered for this study. Group A consisted of 23 professional players from the English Coca Cola League Division One with mean (± SD) age, height, body mass, and percentage body fat values of 25.1 ± 4.5 years, 181 ± 5.9 cm, 75.3 ± 6.4 kg and 10.7 ± 1.1 % respectively. Group B consisted of 16 semi-professional players from the Nationwide Conference North Division mean (± SD) age, height, body mass, and percentage body fat values of 26.2 ± 3.8 years, 183.6 ± 6.3 cm, 82.7 ± 8.2 kg and 13.7 ± 1.7 % respectively.

### Testing Procedures

Aerobic and anaerobic endurance, sprint speed, agility (CODS), body composition (3-site skinfold protocol), height and body mass were assessed immediately following the off-season and 6-week pre-season training periods. Testing took place on grass pitches to maximise ecological validity, and players were instructed to wear the same footwear for both sessions. All sprint times were recorded using Brower Photo-Gate infrared timing gates. Skinfolds were taken at the chest abdomen and thigh by the same tester using Harpenden Calipers. Anthropometric measurements were obtained prior to the exercise tests, with cardio respiratory endurance tested before muscular fitness (ACSM, 2005).

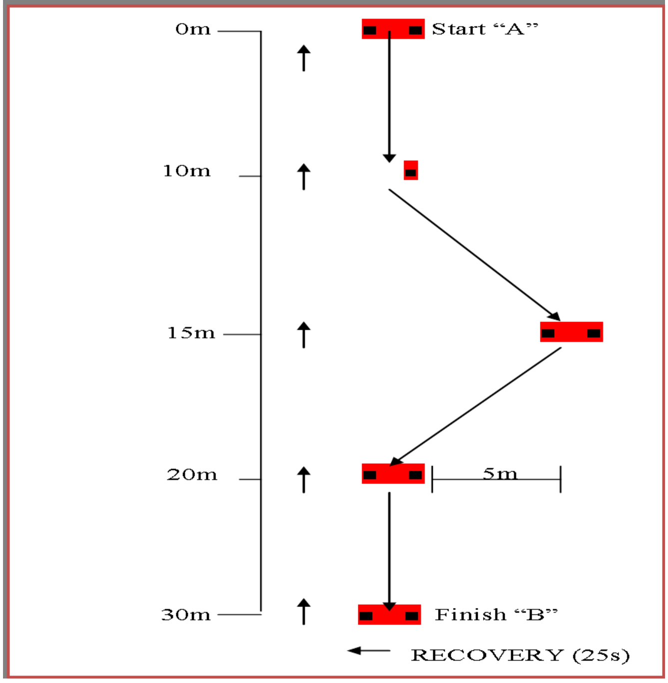
### Yo-Yo Intermittent Endurance Test (YIET) - Level Two

Marker discs were positioned 20 metres apart, with additional markers 2.5m behind the 20m markers. Participants were required to run back and forth (2 x 20m) in time with an audible "beep". At the end of the 40m run (1 'shuttle'), participants either walked or jogged slowly 2.5m around the additional markers back to the start point within 5 seconds. At this point the participants stopped and waited for the signal for the start of the next shuttle. The speed of the shuttle runs progressively increased throughout the test, starting at 11.5 km/h, and participants were given a warning if they did not reach any line of markers on time. The test was terminated when a participant could not follow the set pace of the "beeps" on two separate occasions and/or stopped voluntarily. The total distance covered (i.e. 40m x number of completed shuttles) was reported as the subject's performance measure in the YIET (Bangsbo, 1994).

### Anaerobic Endurance Repeated Sprint Test

The anaerobic sprint test was administered using the protocol as illustrated in in figure 1 (Bangsbo, 2003). Participants were required to sprint as quickly as possible from marker A to B whilst going through the gate at 15m. Participants then had a 25 seconds recovery period in which to return to marker A, with a verbal warning provided every 5 seconds to ensure that participants were prepared for the next trial. Participants completed a total of 7 trials. Times for each trial were recorded and mean time and fatigue index (the difference between the slowest and the fastest trial) were calculated.

Figure 1. Anaerobic endurance repeated sprint course (adapted from Bangsbo, 2003)




### Agility (CODS) Test

The Arrow Agility Test included 7 changes in direction at angles 90°, 120°, 150°, and 180°; forwards, backwards and sideways movements; and 6 transitions between movement patterns. From the start point A, participants were required to sprint forwards to point B, round the outside of the marker and sprint forward to marker C. Participants then side step to point D whilst facing point A. From point D participants turn

180º and sprint forward around point B to point E. Participants then side step to point D whilst facing point A. From point A participants move backwards to point B and sprint forwards to the finish at point A (Figure 2.). Participants performed 2 trail runs to familiarise themselves with the course before completing 3 timed trials at full speed. A two-minute recovery time between each trial was provided.

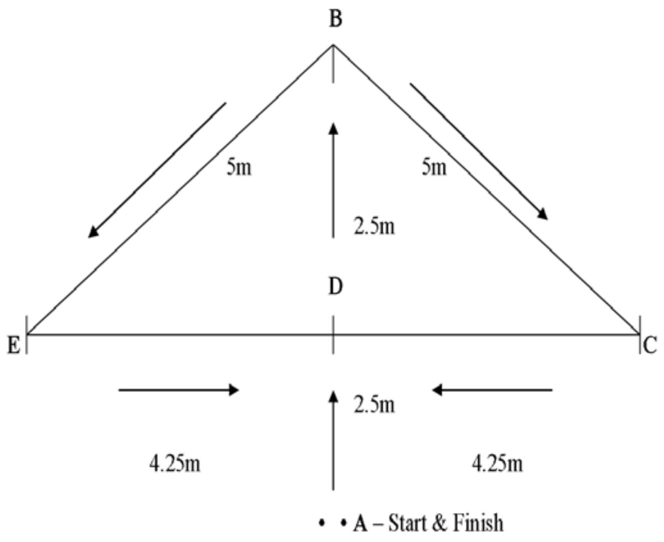



Figure 2. Arrow agility (CODS) course (Smith & Galloway, 2006)

**Sprint Test (5 and 15m)**

Participants were required to sprint as fast as possible from a standing start over the 15m distance, with split times recorded at 5m and 15m. Participants performed 3 trials and the average was recorded. A two-minute recovery was provided between each trial.

**Statistical Analysis**

The Statistical Package for Social Sciences (v16.0; SPSS, inc., Chicago, IL, USA) was used for statistical analysis. Mean and SD were calculated for each of the tests. A mixed design group (playing level) by time MANOVA and univariate follow-up tests were used to examine the differences in the characteristics of the payers following the off-season and pre-season training periods.

**Results**

A mixed design group (playing level) by time MANOVA indicated an effect for differences in performance over time (Wilks lambda 7,28 = .20, P < .01, Partial Eta2 = .90) and an interaction effect for differences in performance over time by playing level (Wilks lambda 7,28 = .20, P < .01, Partial Eta2 = .80). Descriptive statistics for the anthropometric characteristics of the professional and semi-professional players following the off-season (pre) and pre-season training (post) periods are shown in Table 1. Univariate follow-up tests indicated an effect for differences over time (F 1,44 = 54.62, P < 0.01, Partial Eta2 = .62), and an interaction effect in body fat (F 1,44 = 25.78, P < .01, Partial Eta2 = .43). This interaction effect was due to the greater improvements over time of the semi-professional players.

Table 1: Descriptive statistics for the anthropometric characteristics of the professional and semi-professional players

| Group | Age | Height(m) | Body mass(kg) | | Body fat(%) | |
|---|---|---|---|---|---|---|
| | | | Pre | Post | Pre$^{+}$ | Post$^{+}$ |
| Group A (Pro) | 25.1 ±4.5 | 1.82 ±0.06 | 75.3 ±6.4 | 74.6 ±6.3 | 10.7 ±1.1 | 10.6 ±1.1* |
| Group B (Semi- pro) | 26.2 ±3.8 | 1.84 ±0.07 | 82.9 ±8.2 | 82.6 ± 8.7 | 13.7 ±1.7 | 13.3 ±1.7* |

$^{+}$ Significant difference over time (P<0.05)
* Significant interaction between groups (P<0.05)

Descriptive statistics for the battery of field tests for the professional and semi-professional players following the off-season (pre) and pre-season training (post) periods are shown in Table 2. Univariate follow-up tests indicated effects for differences over time in 15m sprint time (F 1,44 = 67.96, P < 0.01, Partial Eta2 = .67), anaerobic endurance (F 1,44 = 18.17, P < 0.01, Partial Eta2 = .35), and the YIET (F 1,44 = 46.98, P < 0.01, Partial Eta2 = .58). Interaction effects were also indicated for 15m sprint time (F 1,44 = 71.36, P < .01, Partial Eta2 = .68), anaerobic endurance (F 1,44 = 5.32, P = .03, Partial Eta2 = .14), and agility (F 1,44 = 5.78, P = .02, Partial Eta2 = .15), over time by playing level.

Table 2. Descriptive statistics for the battery of fitness tests for the professional and semi-professional players

| Field Test | YIET(m) | | Sprint 5m(s) | | Sprint 15m(s) | | Arrow Agility Test(s) | | Repeated Sprint Fatigue Index(s) | | Repeated Sprint mean times(s) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Groups | Pre$^{+}$ | Post$^{+}$ | Pre | Post | Pre$^{+}$ | Post$^{+}$ | Pre | Post | Pre$^{+}$ | Post$^{+}$ | Pre | Post |
| Group A (Pro) | 2178 ±354 | 2419 ±308 | 1.22 ±0.1 | 1.21 ±0.1 | 2.94 ±0.1 | 2.58 ±0.2* | 11.16 ±0.3 | 11.26 ±0.3* | 0.4 ±0.1 | 0.3 ±0.1* | 6.48 ±0.2 | 6.35 ±0.2 |
| Group B (Semi-Pro) | 1677 ±367 | 1895 ±394 | 1.51 ±0.1 | 1.49 ±0.1 | 3.02 ±0.2 | 3.02 ±0.2* | 12.34 ±0.5 | 12.22 ±0.5* | 0.6 ±0.3 | 0.5 ±0.1* | 6.7 ±0.2 | 6.55 ±0.2 |

$^{+}$ Significant difference over time (P<0.05)
* Significant interaction between groups (P<0.05)

## Discussion

This study compared the characteristics of professional and semi-professional football players following the off-season and a 6-week pre-season training periods. Significant improvements in performance over time were observed in body fat, 15m sprint time, anaerobic endurance (fatigue index), and the YIET. Interaction effects for differences in anthropometric characteristics and performance on the battery of fitness test over time by playing level were also observed. The interaction effects for body fat, anaerobic endurance, and agility were due to the greater improvements over time of the semi-professional players, whilst the interaction effect for 15m sprint time was due to the greater improvement over time of the professional players. Whilst the semi-professionals had a higher percentage body fat, and performed at a lower level than their professional counterparts on all fitness tests, they tended to show significantly greater improvement during the pre-season training period. This may be due to a higher level of deconditioning of semi-professional players during the off-season period (Caldwell and Peters, 2009), whilst professional players may return to pre-season in a good physical state as a result of voluntarily remaining active during the off-season (Dunbar and Power, 1997).

The body fat percentages of the professional players remained unchanged following the off-season and pre-season periods and were similar to the values for professional players reported by Sutton et al. (2009). This group of players therefore returned from the off-season period with appropriate levels of body fat. The significantly greater improvement of the semi-professional players (13.7 – 13.3%) could be attributed to their greater accumulation of fat during the off-season period (Reilly, 1990). In terms of anaerobic performance, there were insignificant changes observed in 5m sprint times, and this is consistent with predominately aerobic pre-season training programmes (Aziz et al., 2005). There was however, a greater improvement in 15m sprint time following pre-season training in the professional players. The cause of this is unclear, although could be the result of the inclusion of strength exercises in the pre-season training of the professional players (Stolen et al., 2005). A significant improvement in anaerobic endurance (fatigue index) over time was indicated and this may due to the aerobic based training which improves the ability to recover after a period of high intensity exercise (Bangsbo, 1996). Changes in performance over time were indicated for the YIET, although there was no interaction effect for differences in performance over time by playing level. The differences over time were therefore due to improvements in the YIET in both groups. Similar improvements in aerobic endurance following a pre-season training period of a similar duration have previously been reported (Aziz et al., 2002; Rebelo and Soars, 1997).

## Conclusions

It would appear that the pre-season training programmes used by the professional and semi-professional players may be able to bring about beneficial adaptations in certain key fitness components required for football performance. The battery of fitness test used may also be sensitive to these adaptations. It should be noted however, that there were no significant changes in 5m sprint times, CODS, or average repeated sprint times, and this may be due to a lack of specificity of the pre-season training programmes. Players may therefore commence the playing season without the necessary levels of conditioning for optimal performance. The level of adaptation following pre-season training was greater in the semi-professionals, and this can be attributed to their lower levels of fitness following the off-season period. Pre-season training programmes may therefore need to take into account the conditioning of the players following the off-season period and tailor the training accordingly. Future research could further explore the effectiveness of more football specific pre-season training on a range of fitness components.

## References

American College of Sports Medicine (ACSM) (2005) ACSM's Guidelines for exercise testing and prescription, 7th ed., London: Lippincott Williams & Wilkins.

Aroso, J., Rebelo, A., & Gomes,-Periera, J. (2004) Physiological impact of selected game-related exercises, Journal of Sports Sciences 22(6): 522.

Aziz, A. R., Tan, F., & Teh, K.C. (2002) Variations in selected fitness attributes of professional football players during "A" League season, In Reilly, T., Cabri, J., & Araujo, D. (eds) Science and Football, London: E & FN Spon. pp.139-143.

Aziz, A.R., Tan, F., & Teh, K.C. (2005) A pilot study comparing two field tests with the treadmill run test in football players, Journal of Sports Science and Medicine 4: 105-112.

Bangsbo, J. (1994) The physiology of soccer-with special reference to intense intermittent exercise, Acta Physiologica 15(suppl. 619): 1-156.

Bangsbo, J. (1996) Physiology of training, In Reilly, T., and Williams, M. (eds) Science and Football, 2nd ed., London: Taylor and Francis. pp 47 – 58.

Bangsbo, J. (2003) Fitness training in football: A scientific approach, Auburn, Michigan.

Bangsbo, J., & Michalsik, L. (2002) Assessment of the physiological capacity of elite football performance, in Spinks, W., Reilly, T., & Murphy, A. (eds) Science and Football IV, London: Routledge, pp.53-62.

Barnes, C. (2007) Soccer, in Winter, E.M., Jones, A.M., Davison, R., Bromley, P.D. and. Mercer, T.H. (eds) Sport and exercise physiology testing guideline, London: Routledge.
Bompa, T. O (1999). Periodization, Theory and Methodology of Training 4th Ed, Human Kinetics.

Bradley, P., Sheldon, W., Wooster, B., Olsen, P., Boannas, P. and Krustrup, P. (2009) High-intensity running in English FA Premier League soccer matches, Journal of Sports Sciences 27(2): 159-168.

Caldwell, B.P., and Peters, D.M. (2009) Seasonal variation in physiological fitness of a semi professional soccer team, Journal of Strength and Conditioning Research 23(5): 1370-1377.

Carvalho, C., Roriz-de-Oliveira,P. and Carvalho, A. (2004) Analysis of different parameters of physical condition for footballers in relation to their positional role, Journal of Sports Sciences 22(6): 531-532.

Casajus, J.A (2001) Seasonal Variations in Fitness Variables in Professional Football Players, Journal of Sports Medicine & physical Fitness 41: 463-469.

Dunbar, G.M.J., & Power, K. (1997) Fitness profiles of English professional and semi-professional football payers using a battery of field tests, in Reilly. T., Bangsbo, J., & Hughes, M. (eds) Science and Football III, London: E & FN Spon. pp. 27-31.

Dunbar, G. and Treasure, D. (2005) An analysis of fitness profiles as a function of playing position and playing level in three English premier league clubs, in Reilly, T., Cabri, J., & Araujo, D. (eds) Science and Footbal V, London E & FN Spon. pp.155-159.

Farrow D, Young W, Bruce L. (2005) The development of a test of reactive agility for netball: a new methodology, Journal of Science and Medicine in Sport 8: 52-60.

Gabbett, T.J., Kelly, J.N., and Sheppard, J.M. (2008) Speed, change of direction and reactive agility of rugby league players, Journal of Strength and Conditioning Research 22(1): 174-181.

Gil, S.M., Gil, J., Ruiz, F., Irazusta, A. and Irazusta, J. (2007) Physiological and anthropometric characteristics of young soccer players according to their playing position: relevance for the selection process, Journal of Strength and Conditioning Research 21(2): 438-445.
Gratton, C., & Jones, L. (2004) Research methods for sports studies, London: Routledge.

Helgerud, J., Engen, L. C., Wisloff, U., & Hoff, J. (2001) Aerobic endurance training improves football performance, Medicine and Science in Sports and Exercise 33(11): 1925-1931.

Hoff, J., Wisloff, U., Engen, L. C., Kemi, O. J., & Helgerud, J. (2002) Football specific aerobic endurance training, British Journal of Sports Medicine 36: 218-221.

Hoshikawa, Y., Kanno, A., Ikoma, T., Muramatsu, M., Iida, T., Uchiyama, A., & Nakajima, Y. (2005) Off-season and pre-season changes in total and regional body composition in Japanese professional football league players, in Reilly, T., Cabri, J., & Araujo, D. (eds) Science and Football V, London E & FN Spon. pp.165-172.

Islegen and Akgun (1988) Effects of 6 weeks pre-season training on physical fitness among football players, in Reilly, T., Lees, A., Davids, K. & Murphy, W.J. (eds) Science & Football, London: E & F.N. Spon.

McMillan, K., Helgerud, J., Macdonald, R., & Hoff, J. (2005) Physiological adaptations to football specific endurance training in professional youth football players, British Journal of Sports Medicine 39: 273-277.

Mercer, T.H., Glesson, N.P., & Mitchell, J. (1997) Fitness profiles of professional football players before and after pre-season conditioning, in Reilly, T., Bangsbo, J., & Hughes, M. (eds). Science and Football III, London: E & FN Spon. pp. 112-117.

Metaxas, T.H., Sedelides, T.H., Dipla, K., Koutlianos, N., Zafeiridis, A., Kouidi, E., & Deligiannis, A. (2000) Cardiorespiratory adaptations in professional and amateur football players, Hungarian Review of Sports Medicine 41: 85-94.

Mohr, M., Krustrup, P. & Bangsbo, J. (2002) Performance and physiological characteristics of elite football players during a season, Medicine and Science in Sports and Exercise 34(24).

Mohr, M., Krustrup, P. & Bangsbo, J. (2003) Match performance of high-standard football players with special reference to development of fatigue, Journal of Sports Sciences 21(7): 519-528.

Mohr, M., Krustrup, P. & Bangsbo, J. (2006) Fatigue in football: A brief review, Journal of Sports Sciences 23(6): 593-599.

Ostojic, S.M. (2003) Seasonal alterations in body composition and sprint performance of elite football players, Journal of Exercise Physiology 6(3): 11-14.

Rebelo, A.N., & Soares, J.M.C. (1997) Endurance capacity of professional football players before and after pre-season conditioning, in Reilly, T., Bangsbo, J., & Hughes, M. (eds) Science and Football III, London: E & FN Spon. pp. 106-111.

Reilly, T. (1990) Football, in Reilly, T., Secher, N., Snell, P., & Williams, C. (eds) Physiology of sports, London: E & FN Spon. pp.371-425.

Reilly, T. (1996) Motion Analysis and Physiological Demands, in Reilly, T. and Williams, M. (eds) Science and Soccer. London: Taylor and Francis. pp. 65-79.

Reilly, T. (1996) Fitness assessment, In Reilly, T., and Williams, M. (eds) Science and Football, London: Taylor and Francis. pp.25-47.

Roi, G.S., Pea, G., De Rocco, G., Crippa, M., Benassa, L., Cobelli, A. & Rosa, G. (1993) Relationship between maximal aerobic power and performance of a professional football team, In Reilly T, Larys, J & Stibbe, A. (eds) Science and Football II, London: E & F. N Spon, pp.37-39.

Sassi, R., Reilly, T., & Impellizzeri, F. (2004) A comparison of small-sided games and interval training in elite professional football players, Journal of Sports Sciences, 22(6): 562.

Smith, J., & Galloway, S. (2007) The predictive validity of the "arrow agility test" for university football players, Journal of Sports Sciences 25(3): 364.

Smith, J., & Galloway, S. (2007) The reliability and discriminate validity of the
"Arrow agility test" for football players, Journal of Sports Sciences 25(3): 363-364.

Stolen, T., Chamari, K., Castagna, C., & Wisloff, U. (2005) Physiology of football: An update, Journal of Sports Medicine 35(6): 501-536.

Sutton, L., Scott, M., Wallace, J. and Reilly, T. (2009) Body composition of English Premier League soccer players: Influence of playing position, international status and ethnicity, Journal of Sports Sciences 27(10): 1019-1026.

Svensson, D. and Drust, B. (2005) Testing soccer players, Journal of Sports Sciences 23(6): 601-618.

Tomlin, D.L., & Wenger, H.A. (2001) The relationship between aerobic fitness and recovery from high intensity intermittent exercise, Sports Medicine 31: 1-11.

Young W.B., James, R., and Montgomery, J.R. (2002) Is muscle power related to running speed with changes of direction?, Journal of Sports Medicine and Physical Fitness 42(3): 282-288.

Wragg, C.B., Maxwell, N.S., & Doust, J. H. (2000) Evaluation of the reliability and validity of a football – specific field test of repeated sprint ability, European Journal of Applied Physiology 83: 77-83.

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**Case Study**

# Convulsive syncope following acupuncture treatment: a case study

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**KEY WORDS**

Acupuncture.
Vasovagal.
Convulsive syncope.
Case study.
Adverse event.

**ABSTRACT**

The incidence of adverse events following acupuncture has been described as minimal. However, there are reports of patients undergoing acupuncture suffering from a transient loss of consciousness and upright posture due to global cerebral ischemia; known as convulsive syncope. The current study concerns a 21 year old male patient who was receiving acupuncture treatment for medial tibial stress syndrome. He developed a case of convulsive syncope immediately following the treatment. The patient was referred to a specialist registrar in cardiology. He was then subjected to a range of laboratory tests, including an exercise induced stress test measuring heart rate and blood pressure, which revealed no abnormalities. Consequently, the patient was cleared to return to sport. This current case study suggests a wider consideration is needed to include the athletic population who may have been recently subjected to any of the aforementioned stresses.

The incidence of adverse events following acupuncture have been described as minimal (White, 2009; Stux, 1995; MacPherson et al., 2001; White, 2004), with very low risk of side effects (Cherkin et al., 2003; Lao et al., 2003; Melchart et al., 2004). However, it is difficult to ascertain how rare complications following acupuncture actually are due to the often unreported nature of many adverse incidences. Potential reasons for the lack of reporting include time constraints, apprehension of punishment, and lack of perceived benefit. Peuker and Filler (2004) also suggest that shame, fear of liability, loss of reputation, and peer disapproval are particularly strong disincentives. However, it is important that adverse events are reported in order to improve patient safety, inform best practice decisions, and are used as a valuable aid to learning. Although very rare, one such adverse event following acupuncture is convulsive syncope; defined as a transient loss of consciousness and upright posture due to global cerebral ischemia (Lempert, 2000). When associated with tonic or myoclonic activity, the term convulsive syncope is used to describe the event. Syncope during acupuncture treatment is a form of vasovagal syncope; known also as neurally mediated or neurocardiogenic syncope caused by a sudden decrease of cerebral flow by inhibition of sympathetic flow and increased activation of parasympathetic flow (Chen et al., 1990; Abboud, 1993). Although the effect of acupuncture on the autonomic nervous system is only just beginning to be methodically evaluated in humans (Middlekauff et al., 2004), the timing of the events, in combination with the patients response during and after the treatment would suggest the acupuncture treatment to be this atypical stimuli. A report by Cole (2002) discusses a healthy 25YOA male who received acupuncture bilaterally to ST-36. The patient's gender is suggested to play a role, with convulsive syncope occurring twice as often in the male population (Lin, 1982). Cole et al. (2002) also suggests that inadequate prior nourishment could be a contributing factor; however the most significant contributing factor is placed upon needle phobia, with this being the patients first acupuncture experience. Two subsequent reports by Kung et al. (2005) are without gender preference and, like this report, had previously received acupuncture treatment. Kung et al. (2005) places greater emphasis of the reason for convulsive syncope as fatigue following insomnia and poor sleep patterns prior to the acupuncture treatment.

## Methodology

### Patient history

A 21 year old male (height = 1.74m; mass = 74kg; BMI = 24.4) amateur rugby player with a history of intermittent shin pain presented with left anterio-medial shin pain. The patient was healthy individual with no major recent illnesses or operations (within the last 7yrs). A history of Wolff Parkinson's White at the age of 12 resulted in a successful operation and has not shown any symptoms since. The patient had received acupuncture on one previous occasion for unknown knee pathology at the age of 11 with no adverse effects. No predisposing risk factor concerns were noted for acupuncture treatment. The patient presented with symptoms including diffuse pain along the medial tibial boarder that increased with activity and decreased with rest. A decreased range of motion in dorsiflexion and during the Patla tibialis posterior length test (Patla and Haxby Abbott, 2000) was evident. Pes planus was also noted bilaterally. These signs and symptoms, with the gradual onset and lack of recovery without rest, suggested early stages of medial tibial stress syndrome (Magee, 2008); and was treated for accordingly.

**Treatment and Outcome**

Initial treatment consisted of a combination of medial arch supporting orthocies, soft tissue therapy (to the medial and posterior lower leg) and stretching advice was provided. The athlete continued to train within pain limitations and subsequently presented five days later for the second treatment immediately following a 90 min skills based training session. The patient was treated in a semi-reclining position with bolstered knee support. Three acupuncture points were used unilaterally in the treatment using stainless, sterile acupuncture needles (Classic Plus; 0.22x25mm). The first was inserted perpendicular to the skins surface into tibialis anterior at acupuncture point Stomach 36 (ST 36). The second two were inserted perpendicularly at Spleen 6 and 8 (SP 6 & 8) on the medial aspect of the lower leg. The needles were manually stimulated three times over a 10 minute period. During the treatment the patient complained of heightened sensitivity upon needle stimulation and an uncomfortable pain running inferiorly towards lateral aspect of the left foot. The needles were extracted distally to proximally (SP8, SP6, ST36). Upon extraction of the final needle the patient immediately complained of dizziness and nausea. Advice was given to remain in resting position until the symptoms ceased. After 45-60 seconds the patients face discoloured, he lost consciousness and he began to exhibit an irregular clonic-tonic movement pattern with an upward rolling of the eyes for approximately 10-12 seconds. When the patient regained consciousness, he was able to provide vague responses to basic questioning. The substantial majority of the confusion cleared within a 3-4 minute period, with continued improvement during the subsequent 30 minute monitored period. Over the following 48hours the patient described an increase in appetite, and a general feeling of malaise. Minor visual disturbances were also noted, with a described tunnelling of vision for up to 24 hours.

**Patient follow-up**

The patient was referred to a Specialist Registrar in Cardiology for further investigation. Laboratory tests included exercise induced (treadmill) stress tests to assess blood pressure and heart rate responses. The cardiologists report showed no abnormalities in the test results, with normal heart rate and blood pressure responses. The patient was cleared to return to sport.

**Discussion**

Following acupuncture treatment, the patient of this current study showed the characteristic manifestations of convulsive syncope, including loss of consciousness, postictal confusion <5 minutes, irregular clonic-tonic movements without biting of the tounge or incontinance. The author is only aware of three cases of convulsive syncope within two other reports (Cole et al., 2002; Kung et al., 2005). Whilst considering the likely causes suggested by Cole et al. (2002) and Kung et al. (2005), it is important to consider what the likely causative factors were. Stressful events such as fatigue, nervousness, pain and poor sleep patterns have been shown to interrupt the balance of sympathetic and parasympathetic flow between the heart and the brain (Singh et al., 2002). The training session which preceded the treatment was described as a moderate intensity skills based session. This brings into question the relationship fatigue may have played in contribution to the syncope with potentially altered autonomic function. The second likely stress may have been anxiety. Although the patient did not complain of any anxiety prior to the treatment, they had not received acupuncture for a 10 year period and may have had some unreported anxiety stresses. These previous reports emphasise that although syncope is a rare, but known reaction to acupuncture, convulsive syncope is extremely rare in association with acupuncture. This current report attempts to meet the guidelines set out by Peuker and Filler (2004) for case reports of adverse events related to acupuncture to aid in the standardisation of this type of report, and to ensure that the reports can have greater use than anecdotal revelations. The collection of these reports can help to suggest a level of risk and to encourage discussion regarding procedural changes to increase patient safety.

The patient's previous medical history included Wolf Parkinson's White; a condition that produces abnormal additional electrical pathways in the heart that cause a disruption of the heart's normal rhythm (arrhythmia). This condition can produce symptoms of tachycardia, palpitations, shortness of breath and syncope (Swiderski et al., 1962). However, following a successful operation at 11yrs, the patient has had none of these symptoms. As the subsequent stress tests also showed up no abnormalities, the author does not know of any reason to suspect a link this to convulsive syncope. It is difficult to determine a causative relationship between the small numbers of similar case reports. Although the precise cause of the patient's convulsive syncope cannot be definitively ascertained, it is possible that the stressful and fatiguing events of training and needle anxiety contributed to the convulsive syncope. According to the categorisation of adverse events following acupuncture proposed by Peuker and Filler (2004), it can be considered that it is either probable or certain that the adverse effect can be attributed to the acupuncture and that it is unlikely that it can be attributed to any other concurrent disease or treatment approaches. This report recognises and emphasises the previous recommendations to acquaint patients, in particular new or those who have not received the treatment for a lengthy period of time, to the process and sensations they may experience to reduce anxiety and thus potentially lower the chance of convulsive syncope during acupuncture. Previous authors (Kung et al., 2005) have also recommended particular caution with the older and debilitated patients. This report suggests a wider consideration is needed to include the athletic population who may have been recently subjected to any of the aforementioned stresses.

**References**


Abboud, F. (1993) Neurocardiogenic syncope. *The New England Journal of Medicine*. 328, pp.1117-1120.

Chen, F. Hwang, S. Lee, H. (1990) Clinical study of syncope during acupuncture treatment. *Acupuncture and Electrotherapeutics Research*. Vol. 15, pp.107-119

Cherkin, D., Sherman, K., Deyo, R. and Shekelle P. (2003) A review of the evidence for the effectiveness, safety, and cost of acupuncture, massage therapy, and spinal manipulation for back pain. *Annals of Internal Medicine*; 138(11):898–906.

Middlekauff, H., Shah, J., Yu, J. and Hui, K. (2004) Acupuncture effects on autonomic responses to cold pressor and handgrip exercise in healthy humans. *Clinical autonomic research official journal of the Clinical Autonomic Research Society*, Vol.14 No.2, pp.113-118.

Kung, Y., Chen, F., Hwang, S., Hsieh, J. and Lin, Y. (2005) Convulsive Syncope: An Unusual Complication of Acupuncture *Treatment in Older Patients. The Journal of Alternative and Complimentary Medicine*. Vol.11, No. 3, pp.535-537

Lao L, Hamilton G, Fu J, Berman B. (2003) Is acupuncture safe? *A systematic review of case reports. Alternative Therapies in Health and Medicine* Vol.9, No.1, pp.72–83.

Lempert, T. (2000) Seizures and syncopes. In: Schmidt D, Schachter SC [eds]. *Epilepsy: Problem Solving in Clinical Practice*. Martin Dunitz Ltd. London, pp.19–28.

MacPherson, H., Thomas, K., Walters, S. and Fitter, M. (2001) The York acupuncture safety study: Prospective survey of 34,000 treatmentnts by traditional acupuncturists. *British Medical Journal*. Vol.323, pp.486-487.

Melchart, D., Weidenhammer, W., Streng, A., Reitmayr, S., Hoppe, A. and Ernst, E. (2004) Prospective investigation of adverse effects of acupuncture in 97 733 patients. *Archives of Internal Medicine* Vol.164, No.1, pp.104–105

Patla, C. and Haxby Abbott, J. (2000) Tibialis Posterior Myofascial Tightness as a Source of Heel Pain: Diagnosis and Treatment. *Journal of Orthopaedic & Sports Physical Therapy* Vol. 30, No.10, pp.624-632.

Peuker, E. and Filler, T. (2004) Guidelines for case reports of adverse events related to acupuncture. *Acupuncture in Medicine*. Vol.22, No.1. pp.29-33.

Shen, W. and Weiling, W. (2008) Fainting: Approach to management. In Low, P. and Benarroch, E. [Eds] *Clinical Autonomic Disorders* 3rd Ed. Lippincott Williams & Wilkins, UK.

Singh, R., Kartik, C., Otsuka, K., Pella, D. and Pella, J. (2002) Brain-heart connection and the risk of heart attack. *Biomedicine & Pharmacotherapy*. Vol.56, No.2, pp.257s-265s.

Stux, G. (1995) Techniques of acupuncture. In Stux, G. and Promenz, B. (Eds) *Basics of Acupuncture*. 3rd Ed. Spring-Verlang, New York, pp. 486-487.

Swiderski, J., Lees, M and Nadasthe, A. (1962) *Wolff-Parkinson-White Syndrome in Infancy and Childhood*. From the Department of Pediatrics, Harvard Medical School, and the Sharon Cardiovascular Unit of the Children's. Hospital Medical Center, Boston, Mass., U.S.A.

White, A. (2009) Western Medical acupuncture: a definition. *Acupuncture in Medicine*. Vol.27, No.1, pp.33-35.

White, A. (2004). A cumulative review of the range and incidence of significant adverse events associated with acupuncture. *Acupuncture in Medicine*. Vol.22, Iss.3, pp.122-133.

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**Original research**

# Weight loss and dehydration level in English elite male futsal players

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**KEY WORDS**

Weight loss.
Percentage.
Sweating rate.
Activity time.
Competition.

**ABSTRACT**

Futsal is a high intensity intermittent sport in which accelerations and short sprints are performed at maximal or almost maximal intensity, interspersed by brief recovery periods, during a period of time relatively long. Hydration is the word used to define the process of decrease in the amount of body water. Any activity that causes dehydration will provoke a decrease in the physical performance. An easy way to know the dehydration level of a sportsman is to weigh the subject before and after practising sport. The current study investigates the dehydration level of elite English male futsal players, in two games (i.e. friendly vs. official) and evaluates the resulting values by using studies available in the literature. Eleven (n=11) elite level male futsal players from a top-2 team competing in the Football Association (FA) Futsal National League volunteered to participate in this study. The anthropometric tests used were: mass, height and BMI. Body mass (kg) was recorded before the warm-up and after the game, the subjects wearing only underwear. Besides, the percentage of mass loss, activity time and sweating rate was also calculated. The average activity time was 48.18 ± 3.89 minutes (friendly game) and 48.18 ± 13.47 minutes (official game), with a mean mass loss of 1.27 ± 1.08 kg and 1.09 ± 0.94 kg, respectively. The mass loss percentage was 1.75 ± 1.53% and 1.47 ± 1.22%, respectively. The sweating rate was higher in the official game than in the friendly (11.17 mL/min and 10.44 mL/min). Significant differences were not found in the dehydration level between the two types of game in an elite level English Futsal team. Nevertheless, the results showed that these players obtained a dehydration level that could affect their performance.

## Introduction

Futsal is a high intensity intermittent sport in which accelerations and short sprints (usually with a duration of 1 to 4 seconds) are performed at maximal or almost maximal intensity, interspersed by brief recovery periods (activities of low intensity or pauses), during a period of time relatively long (75-80 minutes) (Álvarez at al., 2001a; Álvarez at al., 2001b; Álvarez at al., 2002; Barbero et al., 2003; Barbero et al., 2004a; Barbero et al. 2004b).

Hydration is the word used to define the process of decrease in the amount of body water. Sportsmen are dehydrated when the liquid loss through sweating takes place in a faster pace than fluid recovery. Any activity that causes dehydration will provoke a decrease in the physical performance.

An easy way to know the dehydration level of a sportsman is to weigh the subject before and after practising sport. In intermittent sports that are practised for less than 3 hours and under no extreme weather conditions, the water loss through breathing is relatively low compared to the water loss through sweating (Maughan et al., 2007). Thus, body weight monitoring is a simple, valid and non-invasive procedure that allows to know the hydration variations through the calculation of the differences in the body weight before and after the exercise (Barbero et al., 2006).

A weight loss percentage higher than 1% causes a decrease in the physical performance (Coyle, 2004; Sawka et al., 2007; Wilmore and Costill, 2007; Murray, 2007). When that percentage is superior to 2%, the subject's cognitive functions, such as perceptive discrimination and reaction time, start to worsen (Cheuvront et al., 2003; Coyle, 2004; Casa et al., 2005; Sawka et al., 2007; Montain, 2008). Reaction time has special relevance in futsal, since futsal is a team sport where performance is affected by both the physical capacity of the players and their cognitive skills used to solve some play demands.

The aim of this study, therefore, was threefold: a) to study the dehydration level of elite English male futsal players, b) to compare the dehydration level obtained in two games (i.e. friendly vs. official), and c) to evaluate the resulting values using the studies available in the literature.

**Methods**

*Participants*

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Eleven (n=11) elite level male futsal players from a top-2 team that competes in the FA (The Football Association) Futsal National League volunteered to participate in this study after having signed the corresponding informed consent. The anthropometric characteristics of the players are included in Table 1. All the players performed the warm-up standardised protocol (30 minutes) and played for at least 10 minutes in every game to be taken into account in the present study. Body weight was analysed in two of the games (a friendly game and an official game), which took place a week apart.

**Table 1.** Anthropometric characteristics of the elite level male futsal team.

| | n | Age (years) | Height (m) | Mass (kg) | BMI ($m/kg^2$) |
|---|---|---|---|---|---|
| Mean | 11 | 24.75 | 1.76 | 71.50 | 23.17 |
| SD | | 3.36 | 0.07 | 8.18 | 2.22 |

*Procedures*

Anthropometric measures were taken, following the Lohmann et al. (1988) instruction. Standing height was measured twice with a precision of 0.1 cm with a stadiometer and a tape measure (SECA Ltd, model 220, Germany), respectively. Body mass (kg) was recorded with a scale SECA (SECA Ltd, Germany) to the nearest 100 g before the warm-up and after the game, the subjects wearing only underwear. For the first measurement, if any player needed to urinate or defecate, they had to do it before stepping up on the scale. For the post-game measure, the players had to clean the sweat off their legs, arms, trunk and face with a towel before recording their body mass, according to Barbero et al. (2006). Body Mass Index (BMI) was calculated using the Quetelec formula: BMI = weight (kg) / height (m2). The percentage of weight loss (% Weight Loss) was estimated according to the following equation:

% Weight Loss = [(Pre-game Weight – Post-game Weight)/Pre-game Weight] x 100

During both games, the players had bottles with water and bottles with a sport drink (Lucozade), the liquid drunk being registered as the sum of the volume of water and the sport drink. The consumption was ad libitum.

The temperature and the relative ambient humidity were recorded with a weather station OREGON SCIENTIC (OREGON, Hunghom, China), using the average value registered since the start of the warm-up until the end of the game (Table 2).

**Table 2.** Date, time, temperature and relative humidity (%) recorded during the games.
* Both games were played at The National Cycling Centre (Manchester – United Kingdom).

| Game | Date | Time | Temperature | Relative Humidity (%) |
|---|---|---|---|---|
| Friendly | 14/11/2010 | 13:30 | 22ºC | 39.33 |
| Official | 21/11/2010 | 15:00 | 23ºC | 40.00 |

The activity time of each player was calculated through the sum of the time played and the time used for the warm-up protocol (standardised at 30 minutes).

**Table 3.** Activity time is the sum of the time played during the game and the standardised 30-minute warm-up protocol.

| | Friendly Game Activity Time (minutes) | Official Game Activity Time (minutes) |
|---|---|---|
| Mean | 48.18 | 48.18 |
| SD | 3.89 | 13.47 |
| Min | 42.00 | 30.00 |
| Max | 55.00 | 70.00 |
| Range | 13.00 | 40.00 |

Finally, although the consumed liquid amount had not been controlled, with the aim to find out the dehydration pattern per minute of physical activity, an estimation of the sweating rate was calculated using an adaptation of Murray's equation (1996):

Sweating rate (mL/min) = [(Pre-game Weight – Post-game Weight) + 500ml]/Activity time

*Statistical Analyses*

Descriptive statistics were performed for all the variables in order to check for the assumptions of normality. Mean ± standard desviation and homogeneity of the parameters were checked with Shapiro-Wilk, and Levene's test. The statistical differences were assessed by using Student's t test. A P value of 0.05 or lower was considered as being statistically significant. An analysis was performed using SPSS version 16.0 (Chicago, IL, USA). In addition, Pearson Correlations were also calculated.

## Results

All the variables were normally distributed. Levene's test showed no violation of homogeneity of variance. The average activity time of the futsal players was 48.18 ± 3.89 minutes (friendly game) and 48.18 ± 13.47 minutes (official game) (table 3), with a mean weight loss of 1.27 ± 1.08 kg and 1.09 ± 0.94 kg, respectively. The weight loss percentage was 1.75 ± 1.53% in the friendly match and 1.47 ± 1.22% in the official match (table 4). Nevertheless, the sweating rate was higher in the official game than in the friendly (11.17 mL/min and 10.44 mL/min, respectively).

**Table 4.** Mass before the game, after the game and % Mass Loss in both games.

| Friendly Game | | | | |
|---|---|---|---|---|
| | Pre-game Mass (kg) | Post-game Mass (kg) | Mass Loss (kg) | % Mass Loss |
| Mean | 73.36 | 72.09 | 1.27 | 1.75 |
| SD | 7.02 | 7.01 | 1.08 | 1.53 |
| Min | 63.00 | 60.00 | 0.00 | 0.00 |
| Max | 90.00 | 87.50 | 3.00 | 4.76 |
| Range | 27.00 | 27.50 | 3.00 | 4.76 |
| | | | | |
| Official League Game | | | | |
| | Pre-game Mass (kg) | Post-game Mass (kg) | Mass Loss (kg) | % Mass Loss |
| Mean | 72.73 | 71.64 | 1.09 | 1.47 |
| SD | 7.03 | 6.61 | 0.94 | 1.22 |
| Min | 60.00 | 58.00 | 0.00 | 0.00 |
| Max | 87.00 | 84.00 | 3.00 | 3.45 |
| Range | 27.00 | 26.00 | 3.00 | 3.45 |

Student's t test showed significant differences between the pre-game weight and the post-game weight, both in the friendly match and in the official one ($p=0.001$ in both games). However, no significant differences were found between the two games (friendly vs. official). If a relation is established between the activity time and the weight loss/weight loss percentage, it can be observed that the dehydration level becomes higher when the activity time increases. However, these correlations are not very high (Table 5), which means that other factors and aspects, such as the environmental conditions or the players' individual characteristics, should be taken into account in order to explain the weight loss and the weight loss percentage obtained.

**Table 5.** Pearson Correlation between dehydration level and activity time.

| Friendly Game | | |
|---|---|---|
| | Mass Loss | % Mass Loss |
| Activity Time | 0.54 | 0.60 |
| | | |
| Official League Game | | |
| | Mass Loss | % Mass Loss |
| Activity Time | 0.47 | 0.46 |

## Discussion

In this study, the elite English futsal players' dehydration level was obtained in a friendly game and an official game. The results showed that the dehydration level reached by these players (1.75 friendly and 1.47% official) is associated with a decrease in the players' performance. A decrease in the body weight of 1% (Ekblom et al., 1970; Walsh et al., 1994; Convertino et al., 1996), 2% (Amstrong et al., 1985; Convertino et al., 1996) or 3% (Sawka, 1992) has previously shown a drop in the sport performance level. The dehydration level found (1.75 and 1.47%) was higher than that reported in other studies in futsal players (Barbero et al., 2006; Hamouti et al., 2007; Martins et al., 2007; García-Jiménez and Yuste, 2010). Barbero et al. (2006) observed a value of 1.7%, 0.8% and 0.9% in professional futsal players. Hamouti et al. (2007) obtained a weight loss percentage of 1.2 ± 0.3% in elite futsal players after a training session. In the study carried out by Martins et al. (2007) in six young futsal players (15-18 years old), values of 0.43 ± 0.41% of percentage of weight loss were obtained after a training session. Finally, García-Jiménez and Yuste (2010) reported values of 1.25 ± 1.08% in five professional Spanish First Division players.

If the values obtained in the friendly game in this study are compared with those in other sports, the dehydration level is similar to that found in football players by Leatt (1986), Kirkendall et al. (1993) and Broad et al. (1996), or in rugby players by Goodman et al. (1985) and Meir et al. (1991), despite the fact that the activity time was much lower than in a football or a rugby match. Maughan et al. (2004) and Shirreffs et al. (2005) found values in football players of 1.59 ± 0.61% and 1.62%, respectively, after a training session. Values that are slightly higher than those found in this study for the official game. Only Broad et al. (1996) and Barbero et al. (2006) reported values lower than 1.0%; Broad et al. (1996) in high level basketball players after a training session (between 0.7 and 1.0%) and Barbero et al. (2006) in professional futsal players after a two-week treatment.

The sweating rate was higher in the official game than in the friendly (11.17 mL/min and 10.44 mL/min, respectively; or 0.7

L/h and 0.64 L/h, respectively), probably due to the different activity time of each player. However, the sweating rate was much lower than the values that Hamouti et al. (2006) observed in professional Spanish basketball players (1.8 L/h and 1.7 L/h) (this substantial difference is caused by the large body area of basketball players), and slightly lower than the values found by Broad et al. (1996) in basketball players (15.3 mL/min) and Barbero et al. (2006) in professional futsal players (12.3 mL/min).

It is important to highlight that, in spite of having time to re-hydrate themselves when the ball is not in their half court, the goalkeepers had an average weight loss of 1.91%; even higher than the outfield players. Finally, no significant differences were found between the two games (friendly vs. official), even if it is widely known that friendly competitions are not as competitive as official competitions. Thus, both friendly and official games could be used to start a re-hydration treatment.

**Conclusions**

In the present study, significant differences were not found in the dehydration level between a friendly game and an official game in an elite level English futsal team. In addition, the results showed that these players reached a dehydration level that could affect their performance. Despite having numerous possibilities to drink liquids (play interruptions, game interruptions, substitutions, time-outs…), the futsal players that participated in this study did not drink enough and so finished the game with dehydration values associated to a decrease in their physical performance. The results suggest that a treatment should be applied to raise the players' awareness about the importance of keeping themselves hydrated. The use of drinks with an adequate content in carbohydrates and electrolytes, like chlorine and sodium, promotes hydration and ensures a suitable recovery of liquids. Finally, it is recommended that the fluid loss through sweating is recovered in 150% after the physical activity.

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**References**

Álvarez Medina, J., Serrano, E., Jiménez, L., Manonelles, P., and Corona, P. (2001a) Perfil cardiovascular en el fútbol-sala: adaptaciones al esfuerzo. *Archivos de Medicina del Deporte XVIII*, 82:143-148.

Álvarez Medina, J., Serrano, E., Jiménez, L., Manonelles, P., and Corona, P. (2001b) Perfil cardiovascular en el fútbol-sala: respuesta inmediata al esfuerzo. *Archivos de Medicina del Deporte XVIII*, 83:199-204.

Álvarez Medina, J., Serrano, E., Jiménez, L., Manonelles, P., and Corona, P. (2002) Necesidades cardiovasculares y metabólicas del fútbol sala: análisis de la competición. *Apunts: Educación física y deportes* 67:45-53.

Amstrong, L. E., Costill, D. L., and Fink, W. J. (1985) Influence of diuretic-induced dehydration on competitive running performance. *Medicine and Science in Sport and Exercise*, 17:456-461.

Barbero Álvarez, J. C., Soto, V., and Granda, J. (2003) Temporary análisis during match play in futsal (indoor soccer) with photogrametric system. *Book of abstracts: Science and Football* 5, 266.

Barbero Álvarez, J. C., Soto, V., and Granda, J. (2004a) Análisis de la frecuencia cardiaca durante la competición en jugadores profesionales de fútbol sala. *Apunts de educación física* 77:71-78.

Barbero Álvarez, J. C., Soto, V., and Granda, J. (2004b) Effort profiling during indoor soccer competition. *Journal of Sports Sciences* 22:500-501.

Barbero Álvarez, J. C., Castagna, C., and Granda, J. (2006) Deshidratación y reposición hídrica en jugadores de fútbol sala: efectos de un programa de intervención sobre la pérdida de líquidos durante la competición. Motricidad. *European Journal of Human Movement*, 17:97-110.

Broad, E. M., Burke, L. M., Cox, G. R., Heeley, P. and Riley, M. (1996) Body weight changes and voluntary fluid intake during training and competition sessions in team sports. *International Journal of Sport Nutrition*, 3:307-320.

Casa, D. J., Clarkson, P. M., Roberts, W. O. (2005) American Collage of Sports Medicine roundtable on hydration and physical activity: consensus statements. *Current Sports Medicine Reports*, 14:115-127.

Cheuvront, S., N., Carter, R., and Sawka, M. N. (2003) Fluid balance and endurance exercise performance. *Current Sports Medicine Reports*, 2: 202-8.

Convertino, V. A., Amstrong, L. E., Coyle, E. F., Mack, G. W. Sawka, M. N., Senay, L. C., and Sherman, W. M. (1996) American College of Sports Medicine Position Stand: Exercise and *fluid replacement. Medicine and Science in Sport and Exercise*, 28(1):1-7.

Coyle, E. F. (2004) Fluid and fuel intake during exercise. *Journal of Sports Sciences* 22:39-55.

Ekblom, B., Greenleaf, C. J., Greenleaf, J. E., and Hermansen, L. (1970) Temperature regulation during exercise dehydration in man. *Acta Physiological Scandinava*, 79:475-483.

García-Jiménez, J. V. and Yuste, J. L. (2010) Weight loss and dehydration in bingings during official futsal matches. *Revista Andaluza de Medicina del Deporte*, 3(2):52-56.

Goodman, C., Cohen, I., and Walton, J. (1985) The effect of water intake on body temperature during rugby matches. *South African Medical Journal* 67:542-544.

Hamouti, N., Estévez, E., Del Coso, J., and Mora, R. (2007) Fluid balance and sweat sodium concentration in elite indoor team sport players during training. (Abstract) In: *The Proceedings of the 12th Annual Congress of the ECSS*, 11-14 July 2007, Jyvaskyla, Finland.

Hamouti, N., Estévez, E., Del Coso, J., Jiménez-Díaz, J. F., and Mora, R. (2006) Rehydrate habits during preseason in a professional basketball team. *Archivos de Medicina del Deporte*, 23(113):210-211.

Kirkendall, D. T. (1993) Effects of nutrition on performance in soccer. *Medicine and Science in Sports and Exercise* 25:1370-1374.

Leatt, P. (1986) The effect of glucose polymer ingestion on skeletal muscle glycogen depletion during a soccer match play and its resynthesis following a match. MSc Dissertation, University of Toronto.

Lohmann, T. G., Roche, A. F., and Martorell, R. (1988) *Anthropometric standardization reference manual*. Champaign, IL: Ed. Human Kinetics.

Martins, M., Aparecida, J., Kleverson, J., Works, R. H., Wagner, R., Bohn, J. H., et al. (2007) A desidrataçao corporal de atletas amadores de futsal. *Revista Brasileira de Prescriçao e Fisiologia do Exercicio* 1(5):24-36.

Maughan, R. J., Merson, S. J., Broad, N. P., Shirreffs, S. M. (2004) Fluid and electrolyte intake and loss in elite soccer players during training. *International Journal of Sports Nutrition*, 14(3):333-346.

Maughan, R. J., Shirreffs, S. M., and Leiper, J. B. (2007) Errors in the estimation of hydration status from changes in body mass. *Journal of Sports Sciences*, 25(7):797-804.

Meir, R. A., Davie, A. J., and Ohmsen, P. (1991) Thermo-regulatory responses of rugby league footballers playing in warm humid conditions. *Sport Health* 8:11-14.

Montain, S. J. (2008) Hydration recommendations for sport. *Current Sports Medicine Reports*, 7(4):187-192.

Murray, R. (2007) Hydration and physical performance. *Journal of the American College Nutrition*, 26(5 Suppl):542-548.

Sawka, M. N. (1992) Physiological consequences of hypohydration: exercise performance and thermoregulation. *Medicine and Science in Sports and Exercise*, 24(6):657-670.

Sawka, M. N., Burke, L. M., Eichner, E. R., Maughan, R. J., and Montain, S. J. (2007) Exercise and fluid replacement. *Medicine and Science in Sports and Exercise*, 39(2):377-390.

Shirreffs, S. M., Aragon-Vargas, L. F., Chamorro, M., Maughan, R. J., Serratosa, L., and Zachwieja (2005) The sweating response of elite professional soccer players to training in the heat. *International Journal of Sports Medicine*, 26(2):90-95.

Walsh, R. M., Noakes, T. D., Hawley, J. A., and Dennis, S. C. (1994) Impaired high-intensity cycling performance time at *low levels of dehydration. International Journal of Sports Medicine*, 15:392-398.

Wilmore, J. H., and Costill, D. L. (2007) *Physiology of Sport and Exercise*. Champaign, IL: Human Kinetics.

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**Original research**

# Effects of limb dominance and ankle bracing on lateral peak impact forces and performance measures in basketball

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**KEY WORDS**

Ankle bracing.
Ankle injuries.
Basketball.
Ground reaction force.
Limb dominance.
Performance.

**ABSTRACT**

Ankle injuries are frequently suffered by basketball players. While ankle bracing has been reported to reduce injury incidence, research is limited regarding lateral peak impact forces (LPIF) and limb dominance. There is also equivocal evidence of ankle bracing's effect on basketball-specific performance. Eight male national league basketball players (n=8) performed 45o cutting manoeuvres, at 4.5m/s to 5.5m/s, past a static defensive opponent on dominant and non-dominant sides; both braced (Aircast Airsport) and un-braced. A further 10 players (n=18; mean + SD, age = 20 + 6 yrs; weight = 720 + 161 N; height = 1.83 + 0.17 m), performed basketball-specific performance tests (20m sprint, agility, and vertical jump tests) in both braced and un-braced conditions. Two-way analysis of variance (ANOVA) with repeated measures revealed significant differences (P = 0.001) between LPIF on dominant (Mean = 639.46 N, SE = 20.6 N) and non-dominant limbs (Mean = 728.96 N, SE = 17.6 N). ANOVA also revealed significant differences (P = 0.005) between LPIF in braced (Mean = 658.15 N, SE = 17.4 N) and un-braced conditions (Mean = 710.27 N, SE = 19 N). Paired-sample T-test reported no significant difference (P = 0.6) in 20m Sprint times with (Mean = 3.22 s, SE = 0.03 s) and without bracing (Mean = 3.23 s, SE = 0.03 s). No significant difference (P = 0.78) was reported in Agility performance with (Mean = 20.46 s, SE = 2.4 s) and without bracing (Mean = 20.51 s, SE = 2.48 s). No significant difference (P = 0.28) was reported in Jump performance braced (Mean = 0.62 m, SE = 0.002 m) and un-braced (Mean = 0.61 m, SE = 0.002 m). Current study suggests using a semi-rigid ankle brace reduces LPIF to the ankle-foot complex, potentially limiting ankle injury without impairing basketball-specific performance.

## Introduction

Basketball is a non-contact sport, which involves the execution of fundamental skills including steps, turns, stops, jumps, and ball handling skills, such as shooting, passing, and dribbling (Krause et al., 1999). During elite basketball games, time motion analysis research shows that players performed 105 bouts of high-intensity activity covering a distance of 991m, made 40-60 maximal jumps, and executed 50-60 changes in speed and direction (McInnes et al. 1995). Despite being classed as a non-contact sport, basketball appears to have one of the highest injury rates of any sport (Meeuwisse et al., 2003). The ankle joint is the most common injury site in basketball (Fong et al., 2007), with lateral sprains most prevalent; accounting for over 90% in one 10-year study (Starkey, 2000). Over half of the total time missed due to injury in basketball is accountable to the ankle and has been attributed to movement patterns that are an integral part of the sport (McKay et al., 1996). These include sharp twisting, turning or cutting components, so crucial to offensive strategies, which are reported to be performed up to 25 times by each player during a game (McClay et al., 1994a; Frederick, 1995). Previous research suggests that 30% of ankle injuries occur during lateral-cutting manoeuvres (McKay et al., 2001; Cumps et al., 2007), when approximately 80% of a player's body weight is placed onto the ankle-foot complex (McClay et al., 1994b; Hawkey and Cloak, 2007). To reduce ankle injury risk, players frequently use ankle support devices, designed to prevent inversion primarily through the restriction of excessive ankle range of motion (ROM) (Verbrugge, 1996; Simpson et al., 1999; Cordova et al., 2002; Eils et al., 2002), maintenance of the ankle's correct anatomical position on impact (Thacker et al., 1999; Wright et al, 2000), via an increase in mechanical stability (Hume and Gerrard, 1998) and improved proprioception (Papadopoulos et al., 2005). While both taping and bracing have been reported to be effective in reducing injury incidence (Bot and Mechelen, 2001; Mickel et al, 2006), tape has been shown to loosen significantly following standardised exercise and sports activities (Hawkey et al., 2010). Semi-rigid braces, which are usually made of neoprene with a thermoplastic insertion on both the medial and lateral sides, are reported to maintain their restrictive effect

(Verhagen et al., 2001) and have been shown to reduce inversion more significantly than other devices during both passive and rapidly induced inversion situations (Eils et al., 2002). Taping has also been reported to be considerably more expensive, and time consuming to apply, than bracing (Mickel et al, 2006). However, despite being widely used in basketball, there are a limited number of full empirical studies published on the effects of bracing on ground reaction forces (GRF) during dynamic, game-like situations.

Sacco et al. (2006) reported that bracing had no effect on mediolateral GRF during cutting manoeuvres with the application of a semi-rigid brace. However, the protocol was not sufficient enough to ascertain the cutting angle and the speed of movement. Hawkey and Cloak (2007) incorporated a static defensive opponent (SDO) into their 45o cutting manoeuvre protocol and found that medial-lateral GRF significantly reduced from 0.8 body weight (BW) to 0.75BW with the application of an ankle brace; similar results were also reported in other studies with comparable protocols (Cloak et al., 2010). The introduction of an SDO is crucial as it produces significant increases in medio-lateral GRF, enabling researchers to analyse forces that more accurately reflect the game environment (Besier et al., 2001; McLean et al., 2004). These previous studies have only focused on the dominant leg though, and controversy exists in the literature over the association between limb dominance and injury risk. Limb dominance, defined by Ford et al. (2003) as one limb demonstrating increased dynamic control as a result of an imbalance in muscular strength and recruitment patterns, has been implicated as a risk factor for lower extremity trauma. Therefore, it has been suggested that athletes who place a greater demand on their dominant limb produce increased frequency and magnitude of forces about the dominant ankle, particularly during high-demand activities that place the ankle at risk (Beynnon et al., 2002). Ekstrand and Gillquist (1983) noted that the dominant leg sustained significantly more ankle injuries in male soccer players, with 92% of ankle injuries affecting the dominant leg. Other studies have also identified limb dominance as a possible risk factor for contact and overuse ankle injuries (Chomiak et al., 2000; Orchard, 2001; Willems et al, 2005; Faude et al. 2006). Faude et al. (2006) observed injuries during training and match exposure times of 143 soccer players during one outdoor season, and found significantly more ankle injuries in the dominant leg. In contrast, Beynnon et al. (2001) found that limb dominance was unrelated to risk of ankle injury for athletes participating in soccer and lacrosse. Similarly, Surve et al, (1994) found that soccer athletes reported no difference in the incidence of ankle injuries between dominant and non-dominant ankles. However, despite reporting on the relationship between limb dominance and injury incidence, these previous studies have not reported any information regarding GRF. This is important as simply reporting injury incidence based on limb dominance does not give an accurate portrayal of the situation. If an individual performs the majority of movements, including cutting manoeuvres, on the dominant limb then it would be a fair assumption that the majority of injuries would be sustained on the dominant limb. According to Murphy et al., (2003) activities such as pushing off, jumping or landing are predominantly performed on the dominant limb, therefore increasing injury risk factors. However, this does not necessarily mean that during an identical movement the dominant limb would be at greater risk of actually sustaining an injury.

An external ankle support's ability to reduce injury risk must also be matched by its capacity not to interfere with an individual's performance. It has been reported that the restriction in ROM, so crucial for injury reduction, is also responsible, possibly via a restriction in plantar-/dorsi- flexion, for the potential to limit performance (Simpson et al., 1999). Hawkey, et al. (2007) found, that the application of a semi-rigid AircastTM ankle brace had no effect on speed or agility, but negatively affected vertical jump performance in college basketball players. Hawkey, et al. (2010), using the same brace and similar testing procedures, found that bracing had no effect on speed, agility or vertical jump performance in professional soccer players. Rosenbaum et al. (2005) reported no significant difference in a variety of soccer related tasks in 10 different ankle braces. Other studies, conducted on a variety of sports and activities, have shown differing results. While some studies report no reductions in performance while wearing an ankle brace (Beriau et al., 1994; Bocchinfuso et al., 1994; Greene and Hillman, 1990; Gross et al., 1994; Hawkey and Scattergood, 2007; Hawkey et al., 2009; Macpherson et al., 1995; Paris, 1992; Pienkowski et al., 1995; Verbrugge, 1996; Wiley and Nigg, 1996), other studies have shown that bracing may adversely affect performance (Burks et al., 1991; Mackean et al., 1997; Paris, 1992). The lack of consensus demonstrated in previous studies may be attributed to methodological differences, participant numbers, performance levels, bracing and taping techniques employed, sample variability, injury status and sporting activity. Due to the lack of empirical evidence regarding the effect of bracing on ground reaction forces, the aim of the current study is firstly to evaluate the effectiveness of an external ankle brace at reducing lateral peak impact forces (LPIF) in male basketball players during a cutting manoeuvre. Secondly, due to the paucity of research on limb dominance, the current study will also aim to establish the role of limb dominance on ankle injury risk. Finally, due to the equivocal evidence currently available, the current study will investigate the effect bracing has on basketball-specific performance.

## Methods

### Participants

With local ethics committee and institutional procedures' approval, 18 male national league basketball players (n=18; mean + SD, age = 20 + 6 yrs; weight = 720 + 161 N; height = 1.83 + 0.17 m) provided informed consent and were screened for any significant lower extremity injury to the ankle or knee within the past two years to reduce any variables that may influence ground reaction forces (GRF) (Caulfield and Garrett, 2004; Houck et al., 2005) or their capability to perform the necessary performance tests.

### Instrumentation

A Bertec force platform (running Pro Vec 5 software) mounted flush with the surface of the floor was used to collect mediolateral GRF data. The frequency of response on the force platform was 1000Hz, in accordance with Sacco et al. (2006) and Hawkey and Cloak (2007) who state to ensure optimal compatibility with dynamic cutting movements frequency response should be set at a minimum of 500Hz. Lateral Peak Impact Force (LPIF), the greatest amount of force exhibited during contact time on the force platform, was recorded as a representation of the maximum mediolateral impact force on the ankle-foot complex in accordance with Cordova et al. (2002) and Hawkey and Cloak (2007). The external ankle brace used during braced conditions was an AircastTM AirsportTM semi-rigid ankle brace (Aircast Inc, Summit, NJ), chosen due to its perceived comfort and ease of application (Rosenbaum et al., 2005), popularity amongst basketball players (Sacco et al., 2004), and prevalence in previous similar studies (Sacco et al., 2004; Sacco et al., 2006; Hawkey and Cloak, 2007; Cloak et al., 2010). Performance times for the agility tests and 20m sprints were recorded using timing gates (Brower Timing Systems, Utah, USA). Jump height performance was assessed using a digital jump mat (Just Jump, Probotic Inc, USA).

### Lateral peak impact force

Following an individualised warm-up, eight (n=8) participants performed cutting manoeuvres past a static defensive opponent (SDO), in the form of a plastic skeleton. Prior to testing, all participants were allowed two practise runs to familiarise them with the protocol and to confirm limb dominance as previously established using methods suggested by Ford et al. (2003; 2005). Approach velocity was required to fall between 4.5m/s and 5.5m/s, reflecting speeds at which cutting movements are typically executed during basketball performance (McLean et al., 1999). Approach velocity was monitored by timing gates, set one metre apart and located one metre forward of the force plate, in order to reduce the influence of running velocity on GRF (Ricard and Veitch, 1994).The SDO was situated 0.2m behind the force platform and in line with the original direction of motion to induce a realistic cutting action when participants made initial contact with the force platform in accordance with McLean et al. (2004). Cutting angles were measured at 45o from the original movement direction in accordance with values typically observed during game situation and those used in previous cutting studies (Sigward and Powers, 2006; Bloomfield et al., 2007; Hawkey and Cloak, 2007). The angle was measured from the centre of the force platform and clearly marked with a corresponding line (using black and yellow adhesive tape) to allow for easy recognition by the participants (Figures 1 and 2). All participants were tested under four conditions:

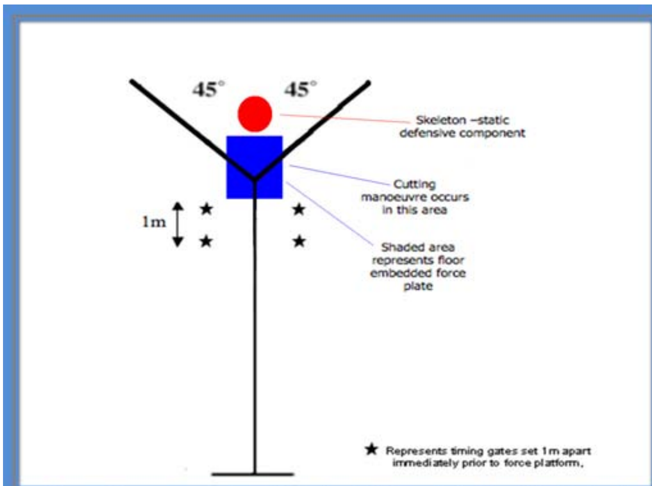



**Figure 1. Diagram of experimental setup (used with permission from Adam Hawkey)**

braced dominant cut, un-braced dominant cut, braced non-dominant cut, un-braced non-dominant cut, in a Latin-square design to reduce any order effects. In braced conditions both ankles were braced. Each participant completed three trials

**Figure 2. Experimental setup; showing the 8m run-up and 45° cutting angle (marked with yellow/black tape), position of light gates, and SDO, (used with permission of Adam Hawkey)**

for each condition, with a ten-minute rest given between each experimental condition, as fatigue has been previously reported to contribute to decreased ground reaction forces (Madigan and Pidcoe, 2003). The LPIF values for three trials in each of the four conditions, for each participant were used for analysis.

### Basketball-specific performance

Following an individualised warm-up, all 18 participants completed three trials in each of two experimental conditions (braced and un-braced) in three separate performance tests: 20m sprint, jump height test, and a basketball-specific agility test. In braced conditions both ankles were braced. The 20m sprint test was used as basketball players spend the majority of their time running forwards over a distance no longer than the regulation court size (Frederick, 1995; McInnes et al. 1995; Krause et al., 1999). The vertical jump test was used to assess the brace's effect on players' jumping performance as vertical movements are regularly undertaken during a game (Frederick, 1995; McInnes et al. 1995; Krause et al., 1999). The basketball-specific agility test, used in accordance with Beriau et al. (1994), was selected due to it being conducted around the three-point line (providing additional ecological validity) and because it incorporates a variety of different movement patterns identified by Frederick (1995) as being integral to basketball. All trials were randomised to reduce any order effects. To reduce the effects of fatigue a ten-minute rest was given between each experimental condition.

## RESULTS

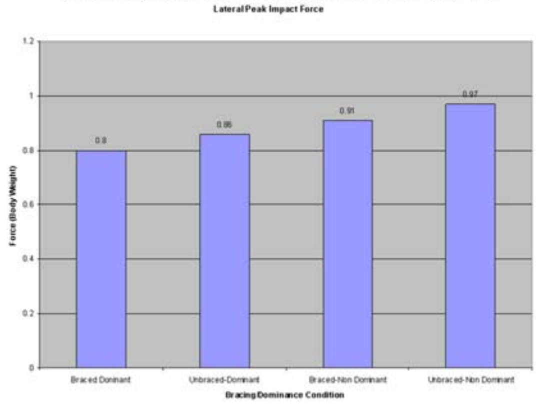
### Lateral Peak Impact Forces (LPIF)

A two-way analysis of variance (ANOVA) with repeated measures was used to assess the factors of bracing and limb dominance on LPIF. The ANOVA revealed a significant difference (P = 0.001) between lateral peak impact forces on the dominant (Mean = 639.46 N, SE = 20.6 N) and non-dominant limb (Mean = 728.96 N, SE = 17.6 N). ANOVA also revealed a significant difference (P = 0.005) between lateral peak impact forces in the braced (Mean = 658.15 N, SE = 17.4 N) and un-braced conditions (Mean = 710.27 N, SE = 19 N). Figure 3 illustrates the effect of limb dominance and bracing on LPIF in relation to an individual's body weight (BW).

### Performance measures

A Paired-sample T-test reported no significant difference (P = 0.6) in 20m Sprint times with (Mean = 3.22 s, SE = 0.03 s) and without a brace (Mean = 3.23 s, SE = 0.03 s). No significant difference (P = 0.78) was also reported in Agility test performance with (Mean = 20.46 s, SE = 2.4 s) and without a brace (Mean = 20.51 s, SE = 2.48 s). No significant difference (P = 0.28) was also reported in Jump test values in braced (Mean = 0.62 m, SE = 0.002 m) and un-braced (Mean = 0.61 m, SE = 0.002 m) conditions.

**Figure 3.** Lateral Peak Impact Force (LPIF), as a unit of BW, in two experimental conditions (braced and un-braced) and on dominant and non-dominant ankles.




### Discussion and implications

The ankle joint is reported to be the most common injury site in basketball, with lateral sprains being the most prevalent type of ankle injury (Fong et al., 2007). These injuries are attributed to movement patterns that are an integral part of the sport, including sharp twisting, turning and cutting manoeuvres (McKay et al., 1996). Previous research has suggested that 30% of ankle injuries occur during lateral-cutting manoeuvres (McKay et al., 2001; Cumps et al., 2007), when approximately 80% of a player's body weight is placed onto the ankle-foot complex (McClay et al., 1994b; Hawkey and Cloak, 2007). To reduce this ankle injury risk players frequently use support devices; primarily bracing. However, despite ankle bracing being reported to be a useful measure in reducing ankle injury incidence, and that they are regularly worn by players, research into their effect on ground reaction forces, and especially relating to limb dominance, is very limited. The current study is the first to investigate the role of both bracing and limb dominance on ground reaction forces during cutting manoeuvres. Lateral GRF data from the unbraced dominant leg in the current study (0.86 body weight) are consistent with values reported by McClay et al. (1994b) and Hawkey and Cloak (2007) (0.8 body weight) highlighting the validity of the current study's protocol. This also suggests that cutting forces, when measured in terms of body weight, are relatively consistent between collegiate, national league, and professional basketball players. Results also show parity with Hawkey and Cloak (2007) and Cloak et al (2010) regarding braced GRF data. The current study suggests that the application of a semi-rigid AircastTM AirsportTM ankle brace significantly reduces lateral peak impact forces during cutting manoeuvres past a static defensive opponent. Previous research has suggested that bracing prevents this inversion primarily through the restriction of excessive ankle range of motion (ROM) (Verbrugge, 1996; Simpson et al., 1999; Cordova et al., 2002; Eils et al., 2002), maintenance of the ankle's correct anatomical position on impact (Thacker et al., 1999; Wright et al, 2000), via an increase in mechanical stability (Hume and Gerrard, 1998) and improved proprioception (Papadopoulos et al., 2005); although none of these variables were directly measured during the current study so.

Previous studies have only reported the effects of bracing on GRF with respect to the dominant limb. The current study progresses this by investigating both dominant and non-dominant limbs. Previous studies have reported significantly more ankle injuries on the dominant leg (Ekstrand and Gillquist, 1983; Willems et al., 2005; Faude et al., 2006; Chomiak et al., 2000; Orchard, 2001; Murphy et al., 2003), although this has been in relation to injury incidence; there is limited research concerned with limb dominance and GRF. It is plausible that increased injury rates are due to players preferring to execute dynamic movements, such as cutting, from their dominant side. However, results of the current study show that it is the non-dominant side that produces significantly higher lateral forces; potentially increasing injury risk. If players prefer to execute dynamic movements from their dominant side, this could be responsible for the increased injury incidence highlighted by previous research. It is also possible that with the majority of cutting manoeuvres performed on the dominant limb that increased neuromuscular activation and improved proprioception help to protect the ankle, compared to the non-dominant limb, during laboratory testing. Therefore, the current study's findings appear important and may possibly change approaches to investigating injury incidence, injury risk and limb dominance.

Results from previous studies regarding bracing and performance have been equivocal. While some have reported no detrimental effect on speed (Bocchinfuso et al., 1994; Hawkey and Scattergood, 2007; Hawkey et al., 2009; Hawkey et al., 2010), agility (Bocchinfuso et al., 1994; Verbrugge, 1996; Hawkey et al., 2009; Hawkey et al., 2010), and jumping performance (Bocchinfuso et al., 1994; Hawkey and Scattergood, 2007; Hawkey et al., 2010), others have shown adverse affects on performance in these tasks (Burks et al., 1991; Beriau et al., 1994; Mackean et al., 1995). Results of the current study suggest that the application of a semi-rigid AircastTM AirsportTM ankle brace has no significant effect on agility, sprint or jump performance in national league basketball players. The non-significant effect in sprint performance reported in the current study could have been expected as previous research, using the same brace, has shown no reduction in sprinting performance (Hawkey and Scattergood, 2007; Hawkey et al., 2007; Hawkey et al., 2010). The non-significant effect in agility performance reported in the current study is also consistent with Hawkey et al. (2007) and Hawkey et al. (2010) and may have been the result of a trade-off between the brace restricting range of motion, as suggested by Cordova et al. (2002), while also providing additional proprioceptive feedback as suggested by Papadopoulos et al. (2005). Jump performance in the current study may have been expected to be reduced due to results of previous research, however this was not the case, and performance was not hindered as it was in studies by Paris (1992) and Hawkey et al. (2007). However, although Hawkey et al. (2007) reported a statistically significant difference in vertical jump height with the application of a brace, the actual difference in performance was only 0.01m. Although not measured during the current investigation, previous research has highlighted a reduction in dorsi-/plantarflexion (Simpson et al., 1999), which has been linked to jumping impairment (Hawkey et al., 2007). Future study should review this variable using motion analysis to determine joint angles. However, it is possible that the reported disparities in jump height with bracing in previous studies could simply be attributed to either an inaccurate method of measurement, from presenting statistically but not practically significant results, or from variations in jumping ability and technique.

This is the first paper to report issues pertaining to limb dominance, bracing and ground reaction forces, in addition to updating information regarding bracing and performance. Therefore, there are some limitations which may warrant addressing in future research. The use of a simulated static defensive opponent, in accordance with McLean et al. (2004), may have enhanced the study's validity, but the participants were aware of the direction they were to perform the cutting manoeuvre. In a basketball game situation, the direction of the cutting manoeuvre may not be pre-determined. It is possible that postural and reflex response may be altered in anticipated movements and that unanticipated manoeuvres may mimic more closely those that occur in a game scenario. Further research is now needed to establish the effect of unanticipated cutting manoeuvres, bracing and limb dominance on GRF. Further research is also needed to establish the effects of bracing in sports-specific protocols. Formally investigating subjective measures of comfort may also be important as this may affect compliance of wearing the brace (Rosenbaum et al., 2005). However, due to the high incidence of ankle injury amongst basketball populations, the current study provides players, coaches and therapists with evidence supporting the use of external ankle supports.

**Conclusions**

The results of the current study suggest that the application of a semi-rigid AircastTM ankle brace significantly reduces lateral peak impact forces during cutting manoeuvres past a static defensive opponent. In addition to this, the non-dominant lower limb may have an increased risk of injury, due to the higher lateral peak impact forces elicited during these cutting manoeuvres. Results also suggest that the application of the brace has no significant effect on basketball-specific agility performance, straight-line sprint speed, or jump height performance. Due to the high incidence of ankle injury amongst basketball populations, the current study provides evidence supporting the use of external ankle supports. Further research is now needed to establish the effect of unanticipated cutting manoeuvres on GRF, and the longer-term effects of bracing on both injury and performance.

**References**

Baumhauer, J.F., Alosa, D.M., and Renstrom, A.F. (1995). A prospective study of ankle injury risk factors. *American Journal of Sports Medicine*, 23, 564–70.

Beriau, M.R., Cox, W.B. and Manning, J. (1994). Effects of ankle braces upon agility course performance in high school athletes. *Journal of Athletic Training*, 29(3), 224–226.

Besier, T.F., Lloyd, D.G., Cochrane, J. and Ackland, T.R. (2001). Anticipatory effects on knee joint loading during running and cutting manoeuvres. *Medicine and Science in Sports and Exercise*, 33, 1176-1181.

Beynnon, B.D., Renstrom, P.A., Alosa, D.M., Baumhauer, J.F. and Vacek, P.M. (2001). Ankle ligament injury risk factors: a prospective study of college athletes. *Journal of Orthopaedic Research*, 19, 213–220.

Beynnon, B.D., Murphy, D.F., and Alosa, D.M. (2002). Predictive factors for lateral ankle sprains: a literature review. *Journal of Athletic Training*, 37, 376–380.

Bloomfield, J., Polman, R., and O'Donoghue, P. (2007). Physical demands of different positions in FA Premier League soccer. *Journal of Sports Science and Medicine*, 6(1), 63-70.

Bocchinfuso, C., Silter, M.R. and Kimura, I.R. Effects of two semi-rigid prophylactic ankle stabilizers on speed, agility and vertical jump. *Journal of Sport Rehabilitation*, 3(2), 125–134.
Bot, S.D.M. and Mechelen, W.L. (1999). The effect of ankle bracing on athletic performance. *Sports Medicine*, 31, 102-108

Burks RT, Bean, B.G. Marcus, R. and Howard, B.B. (1991). Analysis of athletic performance with prophylactic ankle devices. *American Journal of Sports Medicine*, 19(2), 104–106.

Caulfield, B. and Garrett, M. (2004). Changes in ground reaction force during jump landing in subjects with functional instability of the ankle joint. *Clinical Biomechanics*, 19, 617-621.
Chomiak, J., Junge, A., and Peterson, L. (2000). Severe injuries in football players: Influencing factors. *American Journal of Sports Medicine*, 28 (S5), S58–68.

Cloak, R., Wyon, M., and Galloway, S. (2010). The effect of ankle bracing on peak mediolateral ground reaction force during cutting maneuvers in collegiate male basketball players. *Journal of Strength and Conditioning Research*, 24(9):2429-33.

Cumps, E., Verhagen, E. and Meeusen, R. (2007). Efficacy of a sports specific balance training programme on the incidence of ankle sprains in basketball. *Journal of Sports Science and Medicine*, 6, 212-219.

Eils, E., Demming, C., Kollmeier, G., Thorwesten, L., Volker, K., and Rosenbaum, D. (2002). Comprehensive testing of 10 different ankle braces. Evaluation of passive and rapidly induced stability in subjects with chronic ankle instability. *Clinical Biomechanics*, 77, 526–35.

Ekstrand, J. and Gillquist, J. (1983). Soccer injuries and their mechanisms: a prospective study. *Medicine and Science in Sports and Exercise*, 15, 267–270.

Frederick, E. C. (1995, October). *Biomechanical requirements of basketball shoes*. Proceedings of the Second Symposium of the International Society of Biomechanics Working Group on Functional Footwear. Deutsche Sportchochschule, Cologne, Germany, p18-19.

Fong, D.T.P., Hong, Y., Chan, L-K., Yung, P.S-H., and Chan, K-M. (2007). A systematic review on ankle injury and ankle sprains in sports. *Sports Medicine* 37(1), 73-94.

Ford, K.R., Myer, G.D. and Hewett, T.E.. (2003). Valgus knee motion during landing in high school female and male basketball players. *Medicine and Science in Sports and Exercise*, 35, 1745–1750.

Ford, K.R., Myer, G.D. Toms, H.E. and Hewett. T.E. (2005). Gender differences in the kinematics of unanticipated cutting in young athletes. *Medicine and Science in Sports and Exercise*, 37, 24-129.

Hawkey, A. and Cloak, R. (2007). Effect of an AircastTM ankle brace on lateral peak impact forces during cutting movement in male basketball players. *Journal of Sport Sciences*, 26, 239-240.

Hawkey, A., Dando, R., and Scattergood, S. (2007). Effects of ankle bracing on 20m-sprint time, jump height and basketball specific agility test performance in male basketball players. *Journal of Sport Sciences*, 25(S2), S21.

Hawkey, A., and Scattergood, S. (2007). Effects of ankle bracing on mediolateral forces and performance in male long jumpers. *Journal of Sport Sciences*, 25(S2), S46-7.

Hawkey, A., Roberts, S., and Nevill, A. (2009). Effects of an ankle brace on cricket specific agility and sprint performance in male junior cricket players. *Journal of Sports Sciences*, 27(S2), S137.

Hawkey, A., Morrison, D., and Sangha, R. (2010). Effect of ankle taping and bracing on the performance of professional male soccer players. *Journal of Sports Therapy*, 2(1), 11-17.

Houck, J.R., Duncan, A. and De Haven, K.E. (2005). Knee and hip angle and moment adaptations during cutting tasks in subjects with anterior cruciate ligament deficiency classified as noncopers. *Journal of Orthopaedic and Sports Physical Therapy*, 35, 531-540.

Krause, J., Meyer, J. and Meyer, D. (1999). *Basketball Skills and Drills*. Champaign, IL: Human Kinetics.

Mackean L, Bell, G. and Burnham, R.S. (1995). Prophylactic ankle bracing vs. taping: effects on functional performance in female basketball players. *Journal of Orthopaedic and Sports Physical Therapy*; 22(2), 77–81.

Madigan, M.L., and Pidcoe, P.E. (2003). Changes in landing biomechanics during fatiguing landing activity. *Journal of Electromyography and Kinesiology*, 13, 491-498.

McClay, I. S., Robinson, J. R Andriacchi, T. P. Frederick, E. C. Gross, T. Martin, P. Valiant, G. Williams, K. R and Cavanagh, P.R. (1994a). A kinematic profile of skills in professional basketball players. *Journal of Applied Biomechanics* 10(3), 205-221.

McClay, I.S., Robinson, J.R. Andriacchi, T.P. Frederick, E.C. Gross, T. Martin, P. Valiant, G. Williams, K.R. and Cavanagh, P.R. (1994b). A profile of ground reaction forces in professional basketball. *Journal of Applied Biomechanics*, 10, 222-236.

McKay, G.D., Goldie, P.A. Payne, W.R. and Oakes, B.W. (2001). Ankle injuries in basketball: Injury rate and risk factors. *British Journal of Sports Medicine,* 35, 103-108.

McKay, G.D., Payne, W.R. Goldie, P.A. Oakes, B. and Stanley, J. (1996). A comparison of the injuries sustained by female basketball and netball players. *Australian Journal of Science and Medicine in Sport*, 28, 12-17.

McInnes, S.E., Carlson, J.S., Jones, C.J. and McKenna, M.J. (1995). The physiological load imposed on basketball players during competition. *Journal of Sports Sciences*, 13, 387-97.

McLean, S.G., Lipfert, S.W. and Van Den Bogert. A.J. (2004). Effect of gender and defensive opponent on the biomechanics of sidestep cutting. *Medicine and Science in Sports and Exercise*, 36, 1008-1016.

McLean, S.G., Neal, R.J. Myers, P.T. Walters, M.R. (1999). Knee joint kinematics during the sidestep cutting maneuver: Potential for injury in woman. *Medicine and Science in Sports and Exercise*, 31, 959-968.

Meeuwisse W.H., Sellmer, R. and Hagel, B.E. (2003). Rates and risks of injury during intercollegiate basketball. *American Journal of Sports Medicine*, 31, 379-385.

Murphy, D.F., Connolly, D.A. J. and Beynnon, B.D (2003) Risk factors for lower extremity injury: a review of the literature. *British Journal of Sports Medicine*, 37, 13-29.

Orchard, J.W. (2001). Intrinsic and extrinsic risk factors for muscle strains in Australian football. *American Journal of Sports Medicine*, 29, 300–3.

Paris, D.L. (1992). The effects of the Swede-O, New Cross and McDavid ankle braces and adhesive ankle taping on speed, balance, agility and vertical jump. *Journal of Athletic Training*, 27(3), 253-256.

Ricard, M.D. and Veatch, S. (1994). Effect of running speed and aerobic dance jump height on vertical ground reaction forces. *Journal of Applied Biomechanics*, 10, 14-27.

Rosenbaum, D., N. Kamps, K.Bosch, L. Thorwesten, K. Volker, and E. Eils. (2005). The influence of external ankle braces on subjective and objective parameters of performance in a sports-related agility course. *Knee Surgery, Sports Traumatology, Arthroscopy*, 13, 419-425.

Sacco, I.C.N., Takahasi, H.Y. Vasconcellos, A.A. Suda, E.Y. Bacarin, T.A. Pereira, C.S. Battistella, L.R. Kavamoto, C. Lopes, J.A.F. and Vasconcelos, J.C.P. (2004). Influence of ankle devices in the jump and landing biomechanical responses in basketball. *Sociedade Brasileira de Medicina do Esporte*, 10(6), 453-458.

Sacco, I.C.N., Takahasi, H.Y. Suda, E.Y. Battistella, L.R. Kavamoto, C. Lopes, J.A.F. and Vasconcelos, J.C.P. (2006). Ground reaction force in basketball cutting maneuvers with and without ankle bracing and taping. *Sao Paulo Medical Journal*, 124(5), 245-52.

Sigward, S. and Powers, C. (2006). The influence of gender on knee kinematics, kinetics and muscle activation patterns during side-step cutting. *Clinical Biomechanics*, 21(1), 41-48.

Simpson, K.J., Cravens, S. Higbie, E. Theodorou, C. and Delrey, P. A. (1999). Comparison of the sport stirrup, malleoloc, and swede-o ankle orthoses for the foot-ankle kinematics of a rapid lateral movement. *International Journal of Sports Medicine*, 20, 396-402.

Surve, I., Schwellnus, M. P. Noakes, T. and Lombard, C. (1994). A fivefold reduction in the incidence of recurrent ankle sprains in soccer players using the Sport-Stirrup orthosis. *American Journal of Sports Medicine*, 22, 601–606.

Starkey, C. (2000). Injuries and illnesses in the National Basketball Association: A 10-year perspective. *Journal of Athletic Training*, 35(2), 161-167.

Verbrugge, J.D. (1996). The effects of semi-rigid air-stirrup bracing vs. adhesive ankle taping on motor performance. *Journal of Orthopaedic and Sports Physical Therapy*, 23(5), 320–325.

Verhagen, E.A., van Der Beek, A.J., van Mechelen, W. (2001). The effect of tape, braces and shoes on ankle range of motion. *Sports Medicine*. 31(9), 667-677.

Willems, T.M., Witvrouw, E. Delbaere, K. Mahieu, N. and De Clercq, D. (2005) Intrinsic Risk Factors for Inversion Ankle Sprains in Male Subjects: A Prospective Study. *American Journal of Sports Medicine*, 33(3), 415-423.

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