A comparison of the standard barbell bench press and novel Bandbell bench press

by

Ben Staniforth

A thesis submitted in partial fulfilment of the requirements for the degree of MSc (by Research) at the University of Central Lancashire

June 2014

STUDENT DECLARATION FORM

Concurrent registration for two or more academic awards

I declare that while registered as a candidate for the research degree, I have not been a registered candidate or enrolled student for another award of the University or other academic or professional institution

Material submitted for another award

I declare that no material contained in the thesis has been used in any other submission for an academic award and is solely my own work

Collaboration

Where a candidate's research programme is part of a collaborative project, the thesis must indicate in addition clearly the candidate's individual contribution and the extent of the collaboration. Please state below:

Signature of Candidate ____

Type of Award ____

School ____

Abstract

The purpose of this study was to compare the kinematics and whole body sEMG of the barbell with the Bandbell bench press. Twelve subjects with at least five years of resistance training experience volunteered to take part in the study (height, 190 ± 7 cm; bodyweight, 107 ± 16kg). All subjects were familiar with the bench press exercise and had trained it consistently during the four weeks prior to the study at approximately 75% 1RM. Subjects' 10RM bench press was tested (115kg ± 21kg) followed by a 4-7 day rest period. A within-subjects design was used and during experimental testing subjects completed eight bench press trials of increasing intensity, and with a variety of loading conditions. Distance travelled of the bar in the sagittal and transverse plane was measured to assess for instability and to examine any resulting effect of the instability sEMG of the biceps brachii, triceps brachii, pectoralis major, anterior deltoid, external oblique, latisimus dorsii, vastus lateralis and gastrocnemius were recorded. It was found that the distance travelled in the sagittal and transverse planes and mean activation of the biceps brachii and external oblique was significantly greater with the Bandbell at all intensities. Distance travelled in the sagittal and transverse planes and mean activation of the biceps brachii were significantly greater for the Bandbell condition. Therefore, this study shows that the Bandbell is successful at inducing instability during the bench press and produces greater mean activation in stabilising musculature.

Acknowledgements

I would like to take this opportunity to thank my supervisors. First and foremost to Dr. Chris Edmundson who has been a great aid to me whilst undertaking this thesis. Not only by supplying topical knowledge and a much valued opinion but also for being an aid in all other areas which were encompassed within the MSc. Also, to Dr. Darrell Brooks and Dr. Stephen Atkins for their specialist input. A special thank you to Dr. Jonnie Sinclair who has always been generous with his time and more than helpful at every stage. Finally, I would like to thank the members of Ironman Bodybuilding Centre, and especially Martin Brown, without whose participation I would not have a study.

Table of Contents

Chapter 1 - Introduction

The barbell bench press is a popular strength training exercise that is one of the most common and arguably, the most effective tools for developing upper-body strength. There are few gyms in the world that do not have a pressing bench and for good reason: since the 1950s, with the advent of powerlifting, and the 'golden era' of bodybuilding, the bench press has become, possibly, the most widely-recognized resistance training movement in the world (Rippetoe and Kilgore, 2009). The roots of the bench press stem from the decline in popularity of weightlifting in 1950s America. The bench press used to be considered one of the many 'odd lifts' and eventually rose to prominence in the mid-1960s as one of the, now, three lifts that constitute the sport of modern Powerlifting, along with the squat and deadlift. These lifts are performed for one repetition maximums to ascertain maximal upper-body strength. In powerlifting, the loads lifted in the bench press sometimes exceed bodyweight by three times (Keogh, Hume and Pearson, 2006). The National Strength and Conditioning Association recommend the one repetition maximum bench press for measuring upper-body maximum muscular strength in athletic populations (Baechle and Earle, 2008). The bench press is also used as a hypertrophy exercise in bodybuilding and general weight training, involving higher repetitions (Ogasawara *et al.*, 2013).

Resistance training involving balls, platforms and other devices to induce varying degrees of instability has recently enjoyed a surge in popularity. Proponents of instability resistance training deduce that the greater instability and human body interface will stress the neuromuscular system to a greater extent than traditional resistance training methods using more stable surfaces and loads. The advantage of an unstable training environment would be based on the importance of neuromuscular adaptations with increases in strength (Behm and Anderson, 2006). Rutherford and Jones (1986) suggested that specific neural adaptation occurring with training was not increased recruitment or activation of motor units but an improved coordination of agonist, antagonists, synergists and stabilizers. Thus, the inherently greater instability of an unstable platform and body interface should challenge the neuromuscular system to a greater extent than under stable conditions, possibly enhancing strength gains attributed to neural adaptations.

The Bandbell is a length of fibreglass coated bamboo from which kettlebells or weight plates are suspended at either end with rubber resistance bands. The bar has been championed by Louie Simmons of Westside Barbell who states: "We have experimented with the kettlebell and band pressing for over a year. It works. While lowering the bar to the chest, you of course must stop the bar from accelerating, but now you must not stop only the bar but also the kettlebells. This is not easy, as the bands' elasticity causes the kettlebells to lower further even as the bar stops. The kettlebells continue to move not only downward, but in all directions, as an oscillating pendulum, creating a chaotic state. After reaching lock-out, the kettlebells continue to move upward. All the pressing muscles must work together, as they seldom do, to provide stability."

Aims of the Study

Aim 1: Ascertain if the Bandbell bench press elicits a greater amount of instability at a given intensity when compared to the barbell bench press.

Aim 2: Ascertain if the Bandbell bench press elicits a greater muscle activation at a given intensity when compared to the barbell bench press.

Chapter 2 - Literature Review

Bench Press

The bench press actively works the muscles of the anterior shoulder girdle and the triceps, as well as the forearm muscles isometrically. The prime movers are the pectoralis major and the anterior deltoid, which drive the bar up off the chest, and the triceps which drive the elbow to full extension. The pectoralis minor and posterior rotator cuff muscles act to stabilise and prevent the rotation of the humerus during the movement. The other posterior muscles – the trapezius, the rhomboids and other smaller muscles along the cervical and thoracic spine – act isometrically to adduct the shoulder blades and keep the upper back stable against the bench. The latisimus dorsii muscles act to rotate the ribcage up, arched relative to the lower back, decreasing the distance the bar has to travel and adding to the stability of the position. They also act as a counter to the deltoids, preventing the elbows from adducting, or rising up towards the head, while the humerus is driving up out of the bottom, thus preventing the angle between the upper arm and torso from changing during the lift. The muscles of the lower back, hips and legs act as a bridge between the upper body and the ground, anchoring and stabilising the chest and arms as they do the work of handling the bar (Rippetoe and Kilgore, 2009).

Competitive lifting rules and general safety guidelines state that the bar should be kept horizontal at all times during the bench press. As a result, the path of the long axis of the bar has typically been described as a para-sagittal plane movement. Madsen and McLaughlin (1984) describe typical sagittal plane bar paths for both recreational and competitive lifters. For both groups, the path during the descent phase is nearly linear with a slight inferior deviation as the bar travels from the top to the bottom of the lift. During the lift phase, recreational lifters display a bar path that remains inferior (caudal) to the downward path while competitive and elite lifters move the bar closer to the head. In fact, elite lifters display a noticeable, early superior excursion of the bar as compared with the competitive lifters. The authors theorize that this pattern leads to greater lifting success by decreasing the moment created by the bar weight about the shoulder joint during the lift phase. The skilled lifter group also started and finished the exercise with the bar at a lower height than the unskilled lifters. The authors analysed high-speed video of the skilled lifters performing during national and world competitions and did not have direct access to the skilled lifters, therefore, they were not able to measure upper limb length. They were able to estimate upper body length from the video however, and found no significant difference between the skilled and novice groups. With this evidence, the authors suggested that the difference in bar height at the start of the lift was likely due to a wider grip rather than shorter arms for the skilled lifters (Madsen and McLaughlin, 1984).

Instability Training

Instability resistance training is frequently used for performance enhancement, rehabilitation and overall musculoskeletal health. It can involve unstable conditions with body mass or external loads (e.g. dumbbells, barbells) as resistance (Behm and Anderson, 2006). In a recently published review, Behm and Sanchez (2013) state that greater core and limb muscle activation with moderate degrees of instability ensures increased slow- and fast-twitch muscle fibre activation, even when relatively lower forces or power are employed. Coordination of the core muscles may be as or more important than the degree of trunk muscle activation for health and performance. Deep trunk stabilizers (e.g., transversus abdominis and multifidus) respond with anticipatory postural adjustments to movements of the upper or lower limbs. The activation of stabilizing muscles precedes force application when unstable. A delayed reflex response of trunk muscles is a risk factor for low back injuries in athletes. The sensitivity of afferent feedback pathways can be improved with balance and motor skill training, resulting in quicker activation of stabilizing muscles. Instability training may promote co-contractions with shorter latency periods that allow more rapid stiffening and protection of joints. Co-contractile (antagonist) activity increases on unstable surfaces. The role of the antagonist is to control limb position, increase joint stiffness, and provide stability.

Verhagen *et al.* (2004) reported the successful application of balance training to reduce the incidence of ankle sprains in volleyball players. Behm and Anderson (2006) state that the decrease in ankle injury incidence may be due to the improved discrimination of ankle inversion movements found with wobble board training. This improved discrimination indicates a greater stability of the ankle derived from instability training. When extrapolated to the shoulder girdle and the causes of injury in powerlifters (anterior shoulder instability), it may be an indication that specific instability training of the shoulder girdle may also improve stability and decrease injury incidence.

Welsch, Bird and Mayhew (2005) compared barbell and dumbbell bench press (6RM loads) and reported no difference in the neuromuscular activity of the pectoralis major and anterior deltoid. The EMG activity was maintained despite the dumbbell load being only approximately 63% of the barbell load. This suggests that increased neural drive was required to stabilise the dumbbell. However, the authors did not record EMG activity of the agonist/synergist triceps brachii and antagonist biceps brachii muscles. Thus, it is unclear how the increased stability requirement and the reduced absolute load that can be lifted with dumbbells compared with barbell bench press influence the neuromuscular activity of the biceps brachii and triceps brachii. This study does however demonstrate the trend for decreased absolute maximal load that can be lifted when similar movements are performed under stable (barbell bench press) and unstable (dumbbell bench press) conditions.

Marshall and Murphy (2006) investigated muscle activity using surface EMG of upper-body and abdominal muscles during the isolated concentric and eccentric phases of the dumbbell bench press on a flat bench and a Swiss ball. Fourteen resistance trained subjects performed isolated eccentric and concentric bench press repetitions using the two surfaces with a two second cadence at a load equivalent to 60% maximum force output. This was calculated as 60% of each subject's 1RM concentric barbell bench press and for the dumbbell condition the 1RM was obtained using force transducers for each arm, then calculating 60% from this. The results of the study showed that deltoid and abdominal muscle activity was increased for repetitions performed using the Swiss ball. Significant effects of the surface were observed on Rectus Abdominis, Transversus Abdominis/Internal Obliques and Anterior Deltoids. Pectoralis Major and Triceps Brachii showed no significant difference for the surface condition. Biceps Brachii, however, did show a strong tendency towards significance (p = 0.07). Despite this study being very well structured in that it investigated unstable loads and unstable surfaces, separate 1RMs were determined for the different exercises. Also, the separation of the eccentric and concentric phases of the lift is not a normal procedure. No details are given of the time between eccentric and concentric efforts.

Norwood *et al.* (2007) investigated the effectiveness of instability training in the recruitment of core stabilising musculature during a fixed load (9.1 kg) barbell bench press. Surface EMG was measured for six muscles – latisimus dorsii, rectus abdominis, internal oblique, erector spinae and soleus. Four conditions were used: stable flat bench, upper body instability (Swiss ball), lower body instability (flat bench and BOSU ball) and dual instability (Swiss and BOSU ball). The results showed increases in EMG with increasing instability. Specifically, the dual instability condition resulted in the greatest mean muscle activation of the three stability conditions. However, Goodman *et al.* (2008) stated that in order to make an appropriate comparison of muscle activation during a given movement under different conditions, it is important to use the same relative loading. With a fixed load barbell being used between conditions it is likely that the load would have been at very different percentages of subjects 1RM for each specific condition.

In contrast to Norwood *et al.* (2007), Goodman *et al.* (2008) used relative loading for each subject and condition and compared 1RM strength and EMG activity of pectoralis major, anterior deltoid, latisimus dorsii, triceps brachii, biceps brachii and external oblique during the barbell bench press on a stable (flat bench) and unstable surface (Swiss ball). Thirteen subjects underwent testing for 1RM strength for the barbell chest press on both a stable bench and a Swiss ball, each separated by at least 7 days. The results showed there was no difference in 1RM strength or muscle EMG activity for the stable and unstable conditions. However, this lack of observed difference may have been because both efforts were 1RM lifts and therefore maximally engaged the musculature of the whole body, negating any difference between surfaces. If an absolute load was used between conditions as in Norwood *et al.* (2007) an effect of the unstable surface would likely have been seen.

More recently, Uribe *et al.* (2010) examined the effects of a stable surface (flat bench) and an unstable surface (Swiss ball) on muscle activation during the dumbbell bench press (and shoulder press). 16 healthy men performed 1RM tests for the chest press and shoulder press on a stable surface. A minimum of 48 hours post 1RM, subjects returned to perform 3 consecutive repetitions each of the chest press and shoulder press at 80% 1RM under four different randomized conditions (chest press on bench, chest press on Swiss ball, shoulder press on bench, shoulder press on Swiss ball). EMG was recorded for anterior deltoid, pectoralis major and rectus abdominis. The results revealed no significant difference in muscle activation between surface types. In complete contrast to Goodman *et al.* (2008), Uribe *et al.* (2010) used a sensible intensity for loading parameters, however the exercise was submaximal and these results are likely due to the fact that 80% 1RM intensity was used for testing, which should elicit concentric muscular failure at around 8-10 repetitions. With only three repetitions being performed per set in this study, it is likely that subjects were not subjected to the 80% 1RM intensity for long enough to elicit a difference in EMG outputs between conditions. Similarly, McCaw and Friday (1994) found the difference in muscle activation of the medial and anterior deltoids between machine and free weight bench press was greater at a lower (60% 1RM) load than it was at a higher (80% 1RM) load. They suggested that while working against lighter loads, the lowered muscle activity decreases joint stiffness and subsequently emphasises the role of the medial and anterior deltoid as stabilizers of the humeral head in the glenoid cavity. However, Schick *et al.* (2010) did not have similar findings when using 70% 1RM in the bench press and smith machine bench press. The authors state that 70% 1RM may have been sufficiently heavy to elicit enough muscle activity to increase the joint stiffness and limit the stabilizing role of the medial and anterior deltoid.

Schick *et al.* (2010) recorded muscle activation of the anterior deltoid, medial deltoid and pectoralis major, during smith machine and free weight bench press. 70% and 90% 1RM intensities were used for each exercise and two repetitions were performed at both whilst

EMG data was recorded. The main finding was that the activation of the medial deltoid was significantly higher (approximately 160%) during the free weight bench press. They concluded that the instability caused by the free weight bench press necessitates a greater response by the medial deltoid as both a force producer and perhaps more importantly as a stabiliser. This corroborated the findings of McCaw and Friday (1994) and confirmed the important stabilising role of the medial deltoid in the glenoid cavity during the concentric phase of the bench press.

Kohler, Flanagan and Whiting (2010) evaluated the EMG of the anterior deltoid, medial deltoid, triceps brachii, rectus abdominis, external obliques, upper erector spinae and lower erector spinae while lifting stable and unstable loads on stable and unstable surfaces during the seated overhead shoulder press exercise. Thirty resistance trained subjects performed three sets of three repetitions under two load (barbell and dumbbell) and two surface (exercise bench and Swiss ball) conditions at a 10RM relative intensity. Results showed that as the instability of the exercise condition increased, the external load decreased. So, for example, the dumbbell press on the Swiss ball was the least stable and the lightest load was used. Triceps Brachii activation increased with external resistance, where the barbell/bench condition had the greatest EMG activation and dumbbell/Swiss ball condition had the least. The authors correctly state that physical activity is rarely performed with a stable load on an unstable surface; usually the surface is stable and the external resistance is not. The free weight bench press offers instability in all three planes of motion forcing the lifter to contract the muscles in a more natural fashion, to balance in all three planes of motion while exerting force at a velocity that is not constant. This is important to the lifter that wants to increase maximal muscular strength of the prime movers, while engaging the stabilising effect of the prime movers and stabiliser muscles (Schick *et al.,* 2010).

Saeterbakken, Van Der Tillaar and Fimland (2011) compared 1RM and muscle activity in three “chest-press” exercises with different stability requirements – smith machine bench press, barbell bench press and dumbbell bench press. EMG activity of the pectoralis major, anterior deltoid, biceps brachii and triceps brachii were recorded. The dumbbell load was 14% less than for the smith machine and 17% less than that for the barbell bench press. The barbell bench press load was approximately 3% higher than the smith machine. EMG activity of the pectoralis major and anterior deltoid did not differ between conditions. Biceps brachii activation increased with increasing stability requirements (dumbbell bench press>barbell bench press>smith machine bench press). Triceps brachii activity was reduced using dumbbells when compared to barbell and smith machine bench press. This shows how much stability requirements can affect loading of a certain movement. The increased degree of freedom with the dumbbell bench press resulted in 14-17% less loading than for smith or barbell bench press. Saeterbakken, Van Der Tillaar and Fimland (2011) concluded that during rehabilitation it may in some cases be beneficial to achieve high levels of muscle activation while lifting a lighter external load. However, strength trainers/coaches should be aware that the dumbbell chest press does not activate the triceps brachii to the same extent as the conventional bench press. This is why a bench press specific form of instability training is of paramount importance when trying to improve stability in the bench press. A dumbbell press deviates too much from the bench press activation patterns. Neuromuscular adaptations and strength are developed through experience in a given exercise such as the bench press, improving capability in that exercise.

Electromyography (EMG)

Electromyography is the study of the electrical activity in muscle. In humans, it is traditionally performed either by inserting a wire into the muscle (fine wire or indwelling EMG) or by placing electrodes on the skin superficial to the muscle (superficial or surface EMG). The electrodes or wires detect electric current, caused by motor unit action potentials, as it passes through the muscle. The electrical signal, through an electro-chemical pathway, initiates the contraction of the muscle. While it is possible to examine the electrical activity of a single motor unit when using indwelling electrodes, surface EMG will record the activity of multiple motor units. Thus the recording seen in surface EMG represents a sample of the summation of the nearby motor unit action potentials (MUAP). In general, as the frequency of MUAPs increases and more motor units are recruited, the magnitude of the signal recorded will increase. Frequently, to analyse the magnitude of the signal, the raw EMG signal is full wave rectified, and then a low pass filter is employed to create a linear envelope. The area enclosed by this envelope can then be determined and used as a measure of EMG amplitude. Other options for assessment include taking a mean or a peak value over a period of time. Along with the amplitude, frequency content of the signal is often examined and used as an assessment of muscle contraction, particularly fatigue in muscles as well as the type of muscle fibre contracting. The rationale and the physiologic representation of both of these measures will be discussed in later sections.

There are many factors that can alter the relationship between the EMG signal and the force production of a muscle. Some of these factors include: type of EMG electrode (surface versus indwelling), size of the muscle, distance from the electrodes to the muscle fibres, amount of tissue (especially fat) between electrodes and the muscle fibres, contact between the skin and the electrode, and position and orientation of the electrode on or in the muscle (De Luca, 1997). These factors further reinforce that, especially when performing in vivo, normalization of the EMG signal is imperative for deriving a result that has any physiological relevance. There are options available for the method of normalization. Typically, however, the strength of the signal during the measured activity is normalized to, or divided by, a maximal signal that was recorded. This maximal value can be taken during the activity, or it may have been recorded during a separate activity, like a maximal isometric contraction.

Yang and Winter (1984) performed a study focusing on normalization methods as a way of improving the information gathered about muscle activity during gait. Their evaluation criterion was the reduction of variability. They found that normalization using a 50% isometric contraction was inferior to other available normalization methods and in fact, worse than non-normalized data. Normalization using either the peak or the mean of the "ensemble average" proved to be the best methods for reducing variability. Averaging the data presented for the rectus femoris, the vastus lateralis, the biceps femoris and the soleus, the coefficient of variability was 2.7 and 2.9 times greater when normalising to 50% MVC versus normalizing to the peak and the average ensemble taken during walking, respectively. What is meant by "ensemble" is not clearly defined, however these two calculations appear to equate to the peak and the mean EMG level value for a given subject within a stride, which seems to make them similar to a dynamic maximum or a dynamic average taken within a single movement cycle. Burden and Bartlett (1999) compared four methods of normalizing an EMG signal from the biceps of five subjects during an elbow flexion task. The four methods were normalization with respect to (1) peak and (2) mean EMG value during dynamic contraction (Dynamic Peak Method and Dynamic Mean Method, respectively), (3) EMG value during a maximal voluntary isometric contraction (MVIC) and, (4) EMG value during a maximal voluntary isokinetic contraction performed at a similar isokinetic speed and angular position as the activity of interest. The mean EMG value was obtained for each subject during each phase (concentric and eccentric). As there is no “gold standard” for comparison, the authors used a root mean square difference method for evaluation of the difference between each of the first three methods and the fourth normalization method. Their results indicated that either isometric or isokinetic MVC data should be used for normalization.

The ability to use EMG as a method of assessing muscle force is a topic of much debate in the literature. It seems clear that there is some relationship; in general, as the intensity of the motor neuron signal to a muscle increases, the electrical activity in the muscle increases, and the force produced increases as well (Lippold, 1952). Because it is much easier, at least in living humans, to assess the electrical activity of a muscle than it is to measure the force output of a muscle, the EMG-recorded signal has been used to estimate force output of the muscle. Laboratory experiments have done this with reasonable success. In vivo, the relationship is less strong, and holds up better with isometric contractions than dynamic ones. Early research seemed to indicate a nearly linear relationship between force and EMG signal (Lippold, 1952; Bigland and Lippold, 1954) especially in isometric conditions, while later publications provide evidence for a more curvilinear relationship (Clamann and Broecker, 1979; Komi and Buskirk, 1972) especially in dynamic conditions. Bigland-Ritchie suggests that the relationship may be either, and partially depends on the muscle being investigated (Bigland-Ritchie, Kukulka and Woods, 1980) and may actually be a result of the fibre type within the muscle.

To further complicate the matter, many factors affect the maximal force output of a muscle in vivo, including: cross sectional area of the muscle, the ratio of fibre types, muscle velocity, and muscle length, among others. Furthermore, many factors can affect the EMG signal recorded on a given muscle, including: electrode attachment and impedance, size of muscle, distance from muscle to the electrode, fatty tissue, muscle velocity, and electrode movement (De Luca, 1997). Finally, in vivo it is very difficult to measure the force output of a single muscle. More often a torque produced by a group of muscles working together, as well as the contribution of antagonist muscles, is recorded. There are so many factors that can alter the absolute force output of a muscle and also the signal recorded, that estimation of absolute muscle force from EMG signal can be problematic. As a result, the relative level of contraction of a muscle rather than its absolute force output is more often assessed.

The first description of the relationship between EMG signal and muscle fatigue was in 1912. Specifically, Piper described that muscle fatigue can be observed in surface EMG signal as a reduction in EMG signal frequency (Piper, 1912). In addition, Cobb and Forbes (1923) found that muscular fatigue was indicated by an increase in the amplitude of surface EMG signal without a concurrent increase in force. Since that time, research on the topic has progressed to establish two general relationships between EMG signal and fatigue: as fatigue occurs, force output decreases but EMG amplitude remains the same or increases, and there is a shift in the EMG signal toward a lower mean and median frequency (De Luca, 1997). The underlying physiologic reason for this shift is that fatigue creates a change in the muscle fibre membrane permeability, thereby decreasing the conduction velocity of the fibre (Kamen and Caldwell, 1996). Commonly, in sustained submaximal activity, there will also be an increase in the amplitude of the signal without an increase in force production. This is likely caused by an increase in the number of recruited muscle fibres (Kamen and Caldwell, 1996) or an increase in the time duration of the MUAP, which at least in part is due to a decrease in conduction velocity of the action potential, which may be the result of a pH change in the muscle (De Luca, 1997).

Saeterbakken, Van Den Tillaar and Fimland (2011) followed the SENIAM (surface EMG for the non-invasive assessment of muscles) guidelines as laid out by Hermens *et al.* (2000) and placed the electrodes on the dominant side of the body as in Marshall and Murphy (2006). The electrodes (11-mm contact diameter) were placed on the belly of the muscle in the presumed direction of the underlying muscle fibre, with a centre to centre distance of 2cm. Self-adhesive electrodes were positioned at the pectoralis major, anterior deltoid, triceps brachii and biceps brachii. To minimize noise from external sources, the raw EMG signal was amplified and filtered using a preamplifier located as near to the pickup point as possible. Signals were low pass filtered with a maximum cut-off frequency of 8 Hz and high pass filtered with a minimum cut off frequency of 600 Hz, rectified and integrated. The raw EMG signal was root-mean square (RMS) converted to and RMS signal using a hardware circuit network (frequency response 450 kHz, with a mean constant of 12ms, total error ± 0.5%). The RMS converted signal was sampled at a rate of 100 Hz using a 16 bit analogue to digital converter with a common mode rejection rate of 100 dB. The overall mean RMS EMG was calculated for the entire movement as well as separately for the eccentric and concentric phases.

BandBell

The Bandbell Bar is 193cm long and weighs just 2kg. It is made of red oak and a specially-designed fiberglass. It can be safely loaded up to 90kg. It is purported to help avoid surgery in many cases and prevent injury to healthy joints by increasing stability.

Chapter 3 - Pilot Testing

Preceding all experimentation a number of preliminary tests were undertaken, these were essential to the unique nature of the testing for this field. This allowed clearer outlines of what methods to utilise, where no details were obtainable from previous research. The essence of this testing involved the practice of initial beliefs for sensor positioning.

Initial pilot testing took place at a local gym (Ironman Bodybuilding Centre), where many of the participants were regular trainees. A standard 20kg Olympic barbell was set up, on the bench press, with 10kg plates suspended from doubled mini bands at either end (total load = 40kg). Several participants with 10RM bench presses in the range of 100-160kg then took turns to complete sets of ten reps. This load was moderately easy for all participants to press, however there was some kinaesthetic perception of instability by the participants with lower 10RM. This instability was also noted by those observing. More load was added to the bands, however, it was found that with loads above 15kg per band, the load would touch the floor at the bottom of some participants reps. Participants with lower 10RMs were observed to struggle with stabilising the increased loads and kinaesthetic feedback confirmed this instability. It was brought up by one of the participants to try and add load to the bar itself. This was found to result in increased stability. It was therefore hypothesised that there was an inverse relationship between bar mass and perceived stability, relative to the suspended load. Virtually all subjects commented that they felt they could press the load, but were unable to stabilise effectively and that this was an odd sensation unlike any other exercise training mode they had ever used before.

The next stage of pilot testing involved testing the same participants with the BandBell bar. It was found that similar loads to those used with the 20kg barbell could not be emulated with the bandbell. Again, this added to the theory that the mass of/on the bar relative to the load suspended from the bar would greatly influence instability. It was found that loading in the range of 20-40% of 10RM (approximately 15-30% of 1RM) induced instability. With those pilot testing subjects giving feedback that 20% was easy, 30% was moderately difficult and 40% was difficult or very difficult.

Sensor placement was decided by referring to the literature (Soderberg and Knutson, 2000) as well as anecdotal recommendations from strength coaches such as Louie Simmons. It was therefore decided to monitor whole body EMG, with an emphasis on stabilising musculature. EMG sites were then decided based upon the literature (Saeterbakken, Van Der Tillaar and Fimland, 2011) as well as where subjects felt muscles were working harder than usual in the standard bench press. Multiple sites were then tried on different subjects and examined during pressing with both the barbell and bandbell. It was decided that the pectoralis major, anterior deltoid, biceps brachii, triceps brachii (lateral head), latissiumus dorsii, external obliques, vastus lateralis and gastrocnemius (lateral head) were to be used. It was decided to use Root Mean Square (RMS) to process the raw signal.

Initially, loading parameters were determined by using bands in conjunction with a standard barbell. It was observed that subjects could use less load suspended from the bands, than loaded directly onto the bar. This was observed to be due to the fact subjects were noticeably more unstable with the suspended load. It was then decided to add additional load to the barbell with the weight still suspended from bands. This was observed to increase stability. It was therefore hypothesised that the larger the mass of the barbell in relation to the suspended weight, the higher the stability. It was therefore also hypothesised that the lower the load of the barbell, the better to induce instability and therefore higher activation with lesser suspended loads.

A 10RM was chosen as the Bandbell can only be loaded with upto 90kg (three bands with 15kg per side) and is purported to be used for high quality, non-exhaustive, repetition work. Also, for safety reasons, as such a novel and unstable load could be quite dangerous at higher intensities, whereas at lower intensities and higher repetitions, it is much easier to make a subjective decision to end the set.

To extrapolate the findings on the standard barbell with bands to the bandbell. Loading parameters were determined using only suspended load. It was found that the maximum that could be loaded onto a band, without likely making contact with the floor at the bottom of the lift, was 15kg or less. This was therefore set as the maximum load per band. To determine if the mass of the barbell, rather than solely the function, attributed to the increased instability, ankle weights were tried in several different configurations attached around the bandbell. This resulted in the bandbell’s mass being increased to 20kg, the same as a standard Olympic barbell.

Chapter 4 – Method

Experimental Approach to the Problem

A within-subjects design was used to measure the effect of the standard barbell and bandbell on muscle activation during the bench press exercise. Muscle activation was measured using surface EMG (sEMG). Whereas other studies have examined the effect of unstable surfaces (Norwood *et al.,* 2007; Goodman *et al.,*2008) on muscle activation, to our knowledge none have used the bandbell or any similar form of unfamiliar chaotic load instability device. The independent variables included eight different exercise conditions: 20% Bar, 20% Bandbell, 30% Bar, 30% Bar and Bands, 30% Bandbell and Weight, 30% Bandbell, 40% Bar, 40% Bandbell. The independent variables were the EMG measures of the prime movers (triceps brachii, pectoralis major, anterior deltoid) and stabilizers (biceps brachii, latisimus dorsii, external oblique, vastus lateralis, gastrocnemius) associated with performance of the bench press. The root mean squared (RMS) of the EMG amplitude for each muscle, under each condition, was recorded and calculated.

Subjects

Twelve subjects with at least five years of resistance training experience volunteered to take part in the study (height, 180 ± 7 cm; bodyweight, 107 ± 16 kg). All subjects were familiar with the bench press exercise and had trained it consistently during the four weeks prior to the study at 75% 1RM. Subjects' mean 10RM bench press was 115 ± 21 kg. All subjects fulfilled the "advanced" criteria for predicted 1RM bench press to body weight ratio, detailed by Rippetoe and Kilgore (2009). Only men participated because of confounding issues in locating the pectoral muscle beneath adipose and breast tissue in women. Informed consent was obtained from each subject and ethical approval was obtained from the University of Central Lancashire's Ethics committee.

Instrumentation

Height and weight were recorded using a Seca 799 Column Scale (Seca, Birmingham, UK), fitted with the Seca 220 Telescopic Height Measure (Seca, Birmingham, UK). An Eleiko PL Competition Bar (Eleiko Sport AB, Halmstad, Sweden) and various Jordan Olympic Cast Discs (Jordan Fitness, Wisbech, Cambridgeshire, UK) were used.

Procedures

10RM Testing

Upon subjects' arrival at the laboratory, they were briefed on the procedures and the possible risks of the experimental protocol. Height and weight were then recorded. Subjects then performed their usual general warm-up. Once the general warm-up was complete the protocol for establishing 10RM, detailed by Beachle and Earle (2008), was used. Subjects were instructed to use a grip width of 32 inches for all testing (little fingers on marker rings). This was standardised between subjects as placement of weights around the bandbell during the bandbell and weights condition may be prohibitive of subjects utilising their normal grip width. Once this was complete, subjects were advised to complete a series of static stretches and rest before leaving the laboratory.

Experimental Testing

After a minimum of four days and a maximum of seven days after the initial 10RM testing session, subjects were asked to attend the main testing session in the laboratory. Subjects were asked to complete their habitual general warm-up. The testing protocol detailed in table 1 was then performed. Three to five minutes was allowed for the subject to recover between sets and to prepare for the next set. EMG was recorded for each individual set. Once subjects had completed the testing protocol, they were advised to complete a series of static stretching and rest before leaving the laboratory.

Table 1: Experimental testing protocol (X = equipment used during set).

Set	**% of 10RM**	**Equipment Used**			
		PL Bar	Bandbell	Bands	Bar Weights
1	20	X			
2	20		X	X	
3	30	X			
4	30	X		X	
5	30		X	X	X
6	30		X	X	
7	40	X			
8	40		X	X	

Order of testing was not randomised as such a novel, and potentially dangerous condition, even at low intensities, requires a thorough warm-up and to prevent injury. Subjects were given a significant length of time between sets to recuperate and largely negate any order effect.

Loading

A number of different loading methods were used in conjunction with the two bars. With the standard PL bar, weight plates were loaded onto either end for sets one, three and seven. The weight plates were secured using a spring clip. For set four, the weight plates were suspended using a doubled-up mini band looped over the sleeve of the bar and secured in place using a spring clip. With the BandBell bar, weight plates were suspended from doubled-up mini bands secured in the slots at either end of the bar. For set five, four 4.5kg ankle weights were secured around the BandBell at evenly spaced intervals and so as not to interfere with range of motion or hand placement (see Figure 1 and 2). This was to bring the mass of the bar upto that of a standard barbell to ascertain whether it is the function of the bar (i.e.: the flex) or the small mass of the bar that creates the instability.

Figure 1: Bandbell with ankle weights attached.

Figure 2: Bandbell with ankle weights in use.

Kinematics

An eight camera (Qualysis Medical AB, Esperantoplasten 7-9, 411 19 Gothenburg, Sweden) motion analysis system, sampling at 240Hz was used to record the three-dimensional position of a retroreflective marker that had been placed centrally on the bars. The kinematic data were passed through a Butterworth low pass filter with a cut off frequency of 5Hz. This frequency was again chosen based on previous research (Wilson, Elliott, and Kerr, 1989; Wilson, Elliott, and Wood, 1991)**.** First order finite difference equations were used to determine vertical velocity of the bar, which in turn was used to determine the start and finish times for the set. The start of the set was defined as the point where continuous downward (negative) velocity began and the end of the set was defined as the time when the velocity of the bar once again returned to zero.

Electromyography

Surface electromyography (EMG) was used to measure muscle activity for eight muscles. The muscles included the prime movers (triceps brachii, anterior deltoid and pectoralis major) and stabilizers (biceps brachii, external oblique, vastus lateralis and gastrocnemius). Muscle activity was recorded unilaterally on the right hand side. Each EMG site was shaved if necessary and cleansed with alcohol before single differential bipolar electrodes (SX230, Biometrics Ltd, Cwmfelinfach, Gwent, UK) were applied to the skin surface. The sensor contacts were made from 99.9% pure silver bars measuring 10mm in diameter, 0.85mm in depth and spaced 20mm apart (see Figure 3). The EMG sensors were positioned on the centre of the muscle belly, away from the tendons and edge of the muscle and positioned parallel to the orientation of the muscle fibres being measured. One reference electrode was attached to the right wrist using an adjustable wristband (R206, Biometrics Ltd, Cwmfelinfach, Gwent, UK). The EMG recording software was calibrated with the subject resting supine on the bench with hands placed on the top of the thighs and feet flat on the floor (see Figure 4).

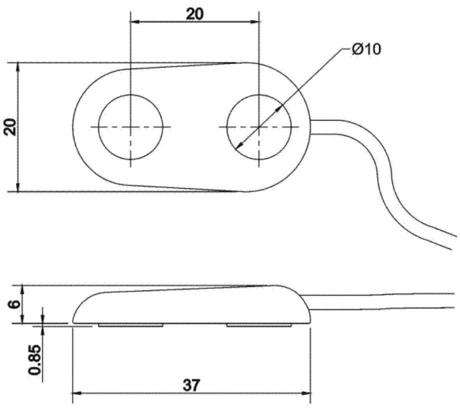

Figure 3: Electrode.

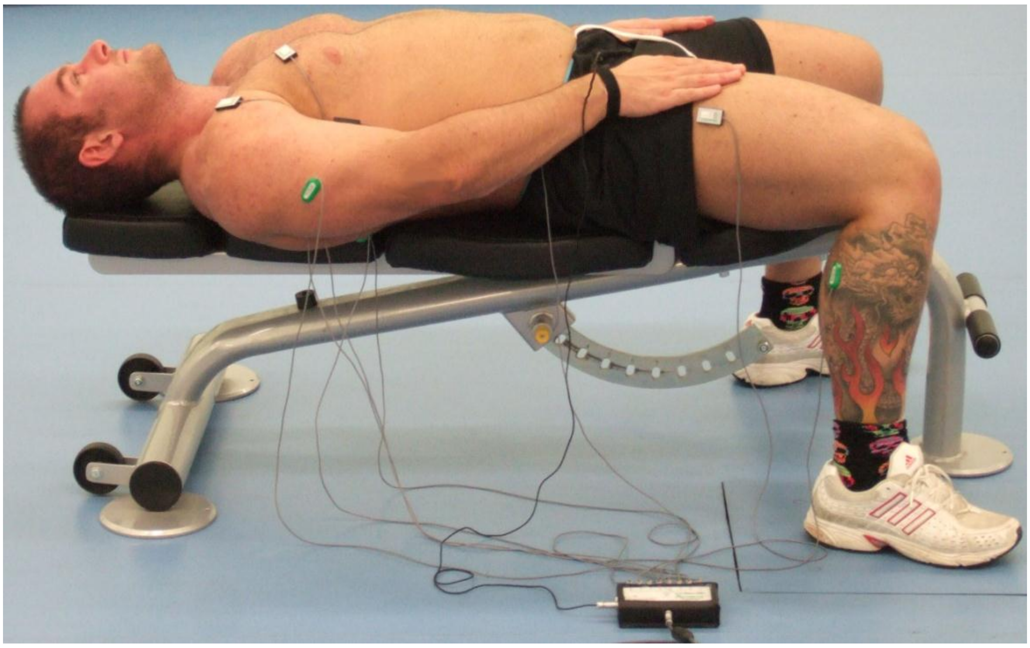

Figure 4: EMG calibration position.

A dual-mode portable EMG and physiological signal data acquisition system (DLK900, Biometrics Ltd, Cwmfelinfach, Gwent, UK) was used for data collection. Data collection and analysis were conducted using DataLINK Version 7.00 (Biometrics Ltd, Cwmfelinfach, Gwent, UK). The data acquisition protocol included a sample frequency (1000 Hz) and band pass filter (20-460 Hz). The RMS was calculated for the combined eccentric and concentric phases of the movement using a 200ms window. The RMS values for each muscle were normalized to the peak activation of a dynamic ten repetition (40% 10RM) BandBell bench press set (1^{st} set). EMG data was not normalised to a maximal voluntary contraction (MVC) as is normally performed. This was because the muscle activity was measured during dynamic movement and most MVC procedures are performed during an isometric contraction. The use of an isometric MVC was not relevant for this study. Also, it was not a purpose of this study to provide relative muscle activity values, because a relative load was used to standardise the experimental workload between conditions (Marshall and Murphy, 2006).

Intensity

Intensity analysis compared the bar and BandBell sets at 20, 30 and 40% 10RM.

Condition

Condition analysis compared all four sets at 30% 10RM with the bar, barbell and bands, BandBell and weights and BandBell.

Statistical Analysis

Paired samples t-tests were used to examine intensity. One way repeated measures ANOVA were used and post-hoc t-tests with Bonferroni correction were used to examine condition. (SPSS version 19.0; SPSS, Inc., Chicago, IL). All results are presented as means ± standard deviations. Statistical significance was set as $P \leq 0.05$.

The calculation of sample size was carried out with a $\alpha = 0.05$ (5% chance of type I error) and $1 - \beta = 0.80$ (power 80%) and using the results provided from Saeterbakken, Van Der Tillaar and Fimland (2011) who found significant difference in muscle activity under stable and unstable conditions. This provided a sample size of $n = 12$ for this study.

Chapter 5 - Results

Intensity

Kinematics

Sagittal Plane

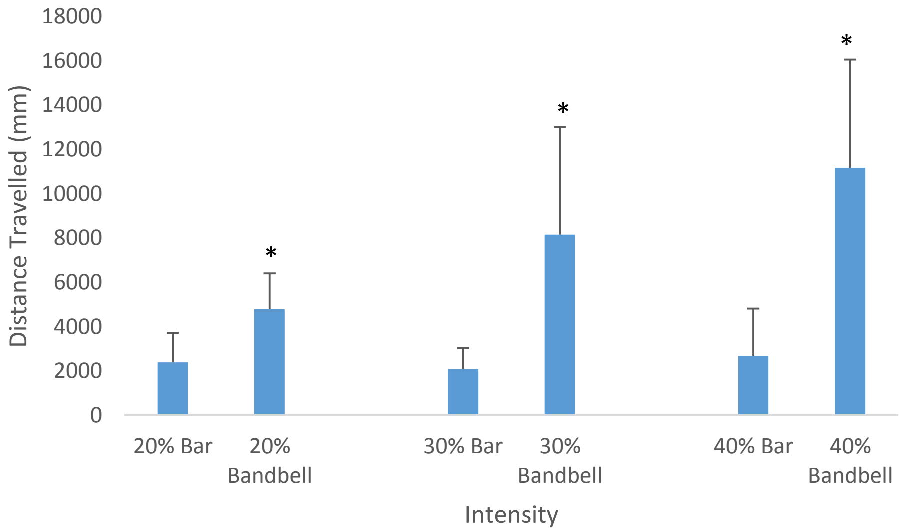

Figure 5: Mean (± SD) sagittal plane distance travelled during intensity trials (* = p ≤ .05)

Paired samples t-tests determined that distance travelled in the sagittal plane was significantly greater with the BandBell than the bar at 20% ($t(11) = -11.15$, $p = .000$), 30% ($t(11) = - 4.08$, $p = .002$) and 40%($t(11) = -7.13$, $p = .000$) 10RM intensities.

Transverse Plane

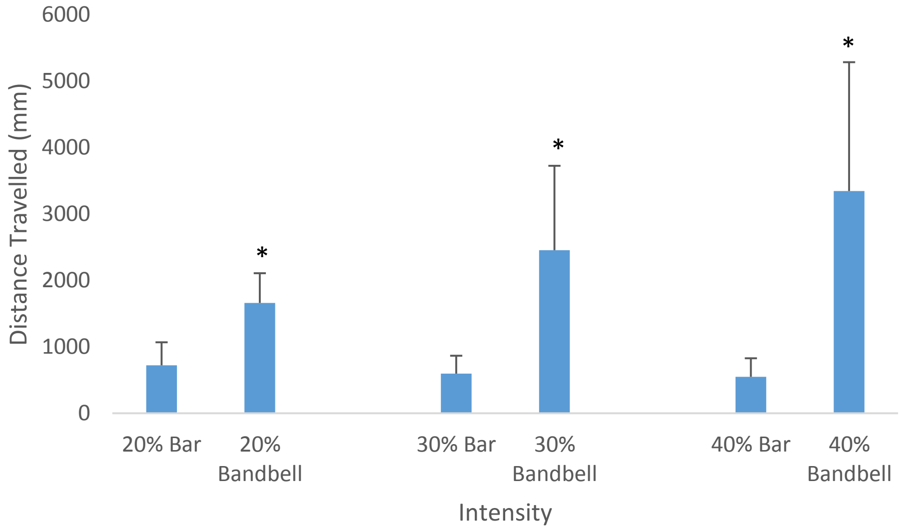

Figure 6: Mean (± SD) transverse plane distance travelled (mm) during intensity trials (* = p ≤ .05)

Paired samples t-tests determined that distance travelled in the transverse plane was significantly greater with the BandBell than the bar at 20% ($t(11) = -8.45$, $p = .000$), 30% ($t(11) = -5.39$, $p = .000$) 40% ($t(11) = -4.86$, $p = .001$) 10RM intensities.

sEMG

Biceps Brachii

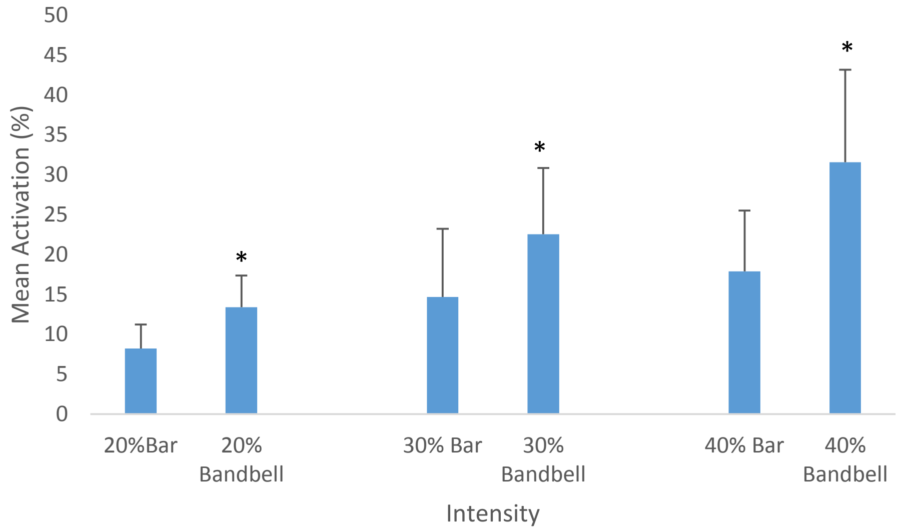

Figure 7: Mean (± SD) biceps brachii mean activation during intensity trials (* = p ≤ .05)

Paired samples t-tests determined that biceps brachii mean activation was significantly greater with the BandBell than the bar at 20% (t(11) = -4.48, p = .001), 30% (t(11) = - 3.30, p = .008) and 40% (t(11) = -2.99, p = .014) 10RM intensities.

Triceps Brachii

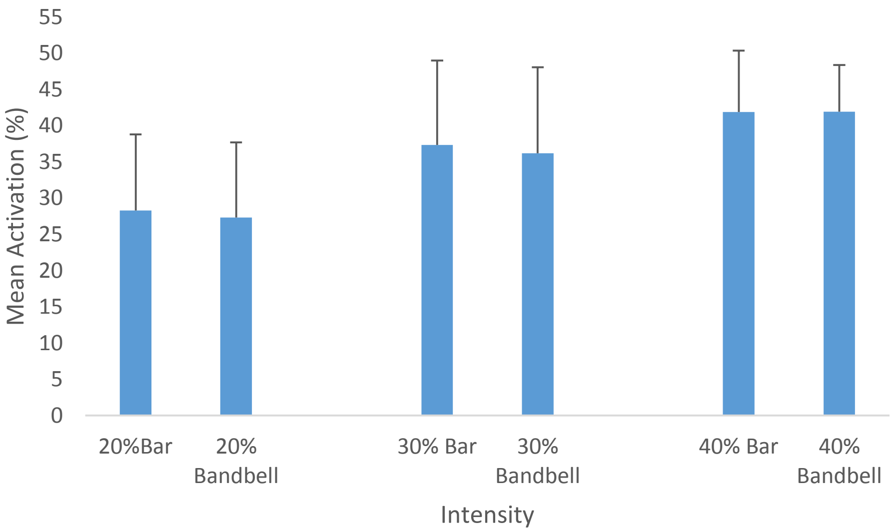

Figure 8: Mean (± SD) triceps brachii mean activation during intensity trials

Paired samples t-tests determined that triceps brachii mean activation did not significantly differ between the BandBell and bar at 20% ($t(11) = .774$, $p = .457$), 30% ($t(11) = .880$, $p = .400$) and 40% ($t(11) = -.022$, $p = .983$) 10RM intensities.

Pectoralis Major

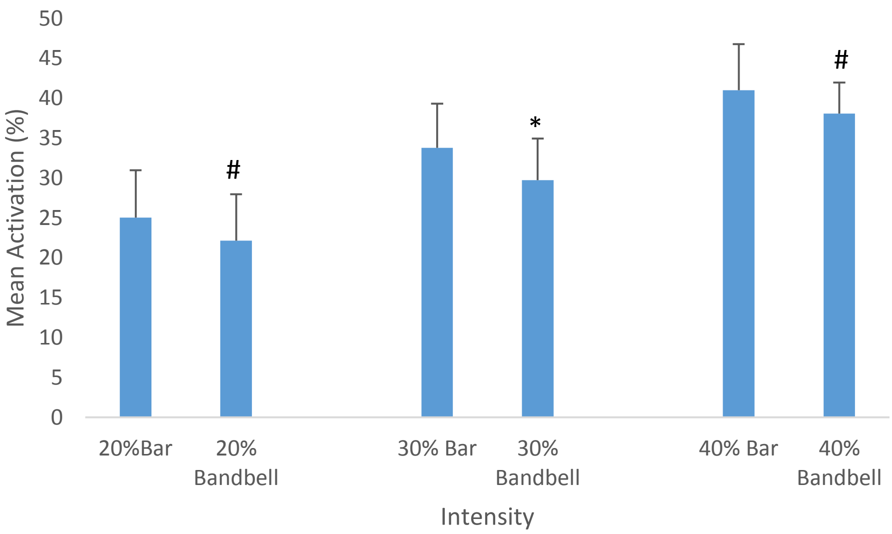

Figure 9: Mean (± SD) pectoralis major mean activation during intensity trials (* = $p \leq .05$, # = $p \leq .10$)

Paired samples t-tests determined that pectoralis major mean activation was significantly lower with the BandBell than the bar at 30% ($t(11) = 3.46$, $p = .006$) and was approaching significance at 20% ($t(11) = 2.05$, $p = .067$) and 40% ($t(11) = 2.10$, $p = .063$) 10RM intensities.

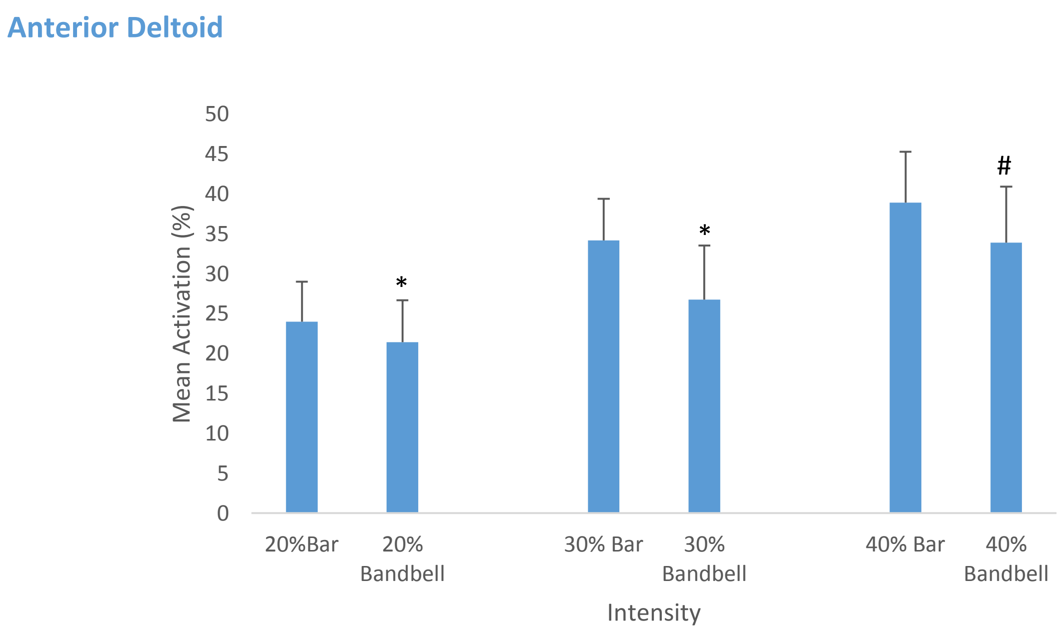

Figure 10: Mean (± SD) anterior deltoid mean activation during intensity trials (* = p ≤ .05, # = p ≤ .10)

Paired samples t-tests determined that anterior deltoid mean activation was significantly lower with the BandBell than the bar at 20% ($t(11) = 4.59$, $p = .001$), 30% ($t(11) = 3.49$, $p = .006$) and was approaching significance at 40% ($t(11) = 2.14$, $p = .058$) 10RM intensities.

Latisimus Dorsii

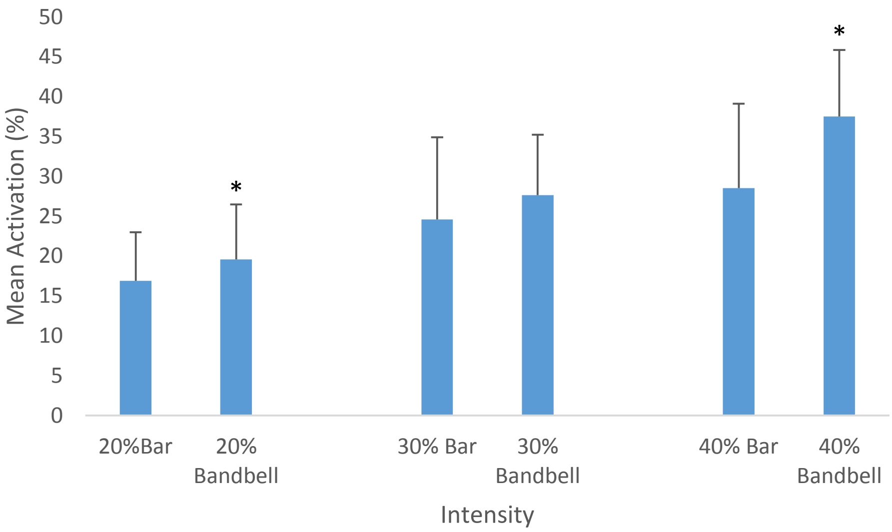

Figure 11: Mean (± SD) latisimus dorsii mean activation during intensity trials (* = p ≤ .05)

Paired samples t-tests determined that latisimus dorsii mean activation was significantly greater with the BandBell than the bar at 20% ($t(11) = -2.18$, $p = .054$) and 40% ($t(11) = -3.17$, $p = .010$) 10RM intensities, however, there was no significant difference at 30% ($t(11) = -1.28$, $p = .228$) 10RM intensity.

External Oblique

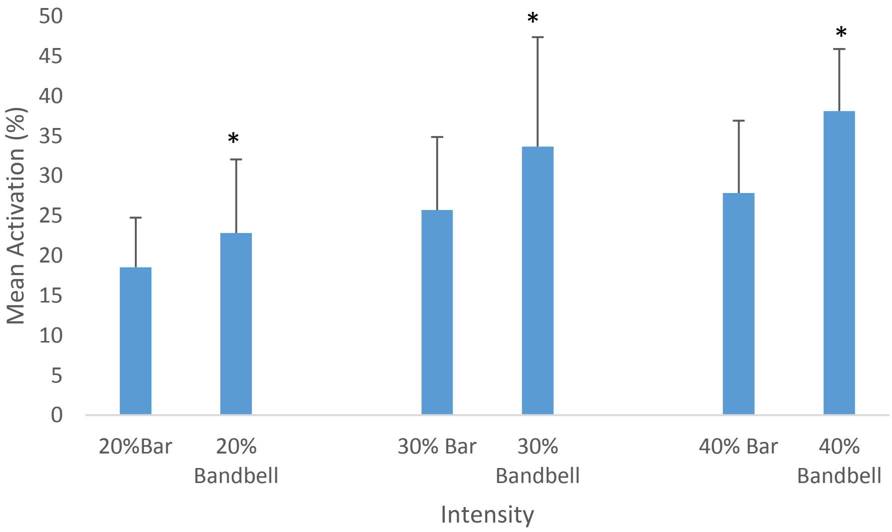

Figure 12: Mean (± SD) external oblique mean activation during intensity trials (* = p ≤ .05)

Paired samples t-tests determined that external oblique mean activation was significantly greater with the BandBell than the bar at 20% (t(11) = -2.19, p = .054), 30% (t(11) = -2.32, p = .043) and 40% (t(11) = -6.26, p = .000) 10RM intensities.

Vastus Lateralis

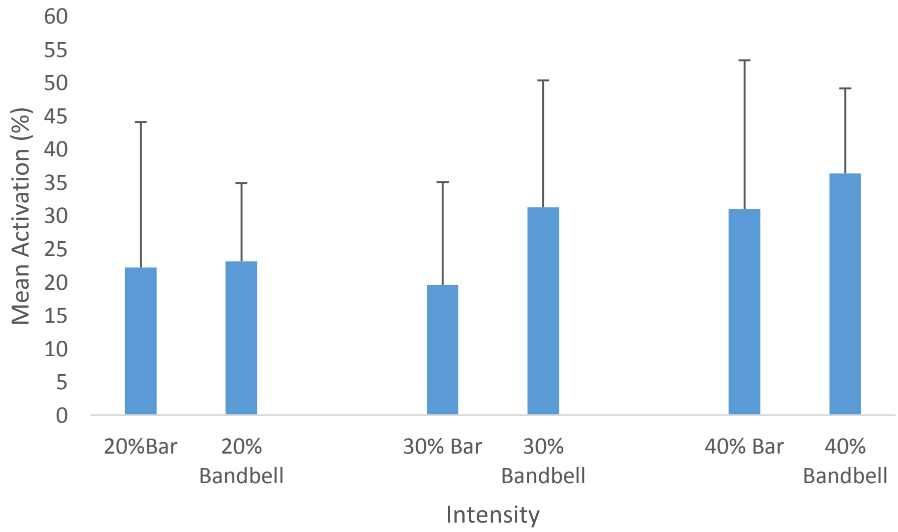

Figure 13: Mean (± SD) vastus lateralis mean activation during intensity trials

Paired samples t-tests determined that vastus lateralis mean activation did not significantly differ between the BandBell and bar at 20% (t(11) = -.14, p = .892), 30% (t(11) = -1.71, p = .117) and 40% (t(11) = -1.025., p = .329) 10RM intensities.

Gastrocnemius

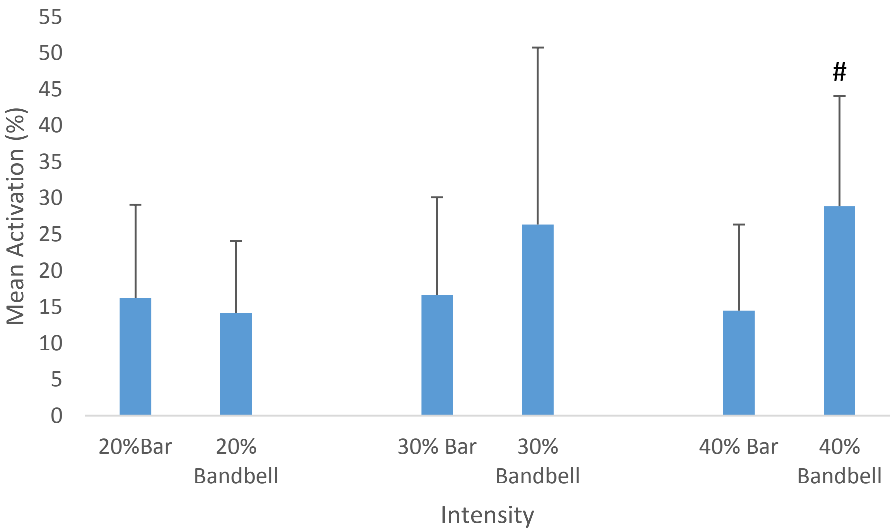

Figure 14: Mean (± SD) gastrocnemius mean activation during intensity trials (# = p ≤ .10)

Paired samples t-tests determined that gastrocnemius mean activation did not significantly differ between the BandBell and the bar at 20% (t(11) = .676, p = .514) and 30% (t(11) = -1.13, p = .286)10RM intensities, however, greater mean activation with the BandBell than the bar was approaching significance at 40% (t(11) = -2.120., p = .060) 10RM.

Condition

Kinematic Data

Sagittal Plane

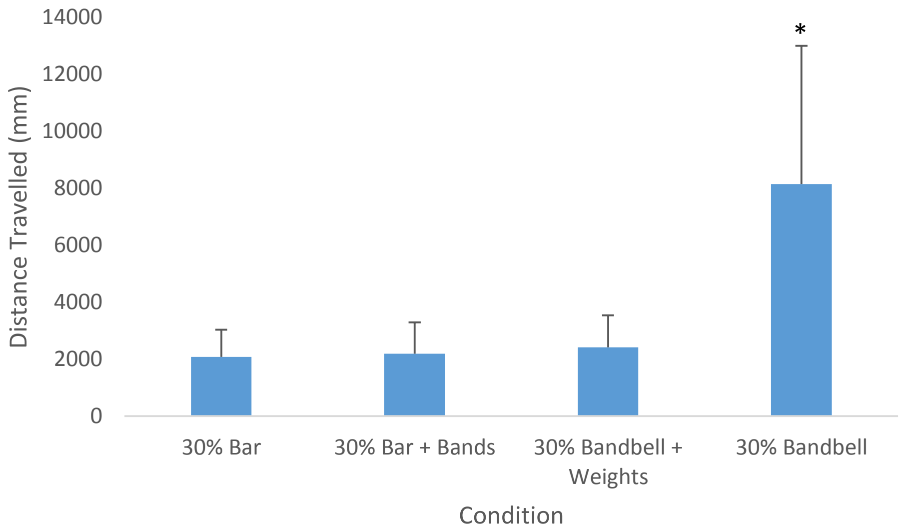

Figure 15: Mean (± SD) sagittal plane distance travelled during condition trials (* = p ≤ .05)

A repeated measures ANOVA with a Greenhouse-Geisser correction determined that distance travelled in the sagittal plane differed significantly between loading conditions ($F(1.06, 11.63) = 15.90$, $P = .000$). Post hoc tests using the Bonferroni correction revealed that distance travelled during the 30% BandBell trial was significantly greater than any of the other conditions ($p \leq .05$).

Transverse Plane

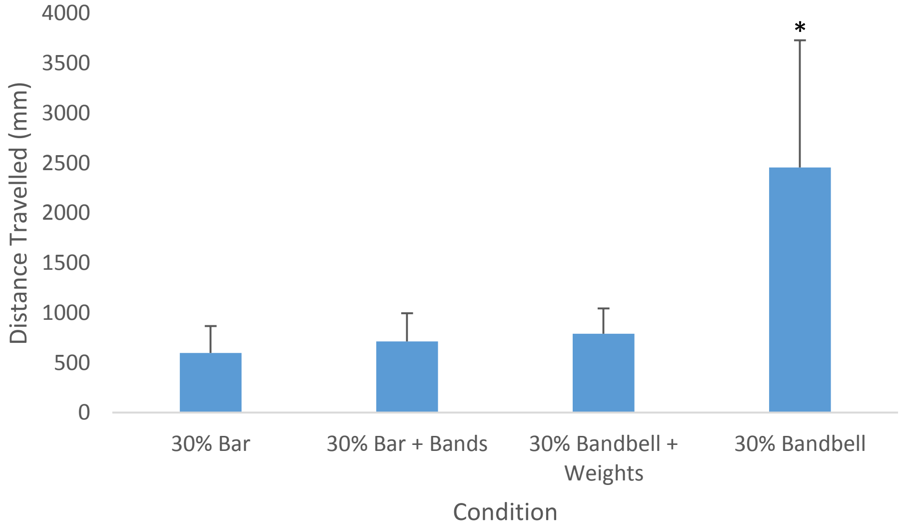

Figure 16: Mean (± SD) transverse plane distance travelled during condition trials (* = $p \leq .05$)

A repeated measures ANOVA with a Greenhouse-Geisser correction determined that distance travelled in the transverse plane differed significantly between loading conditions ($F(1.16, 12.73) = 23.85$, $P = .000$). Post hoc tests using the Bonferroni correction revealed that distance travelled during the 30% Bandbell trial was significantly greater than any of the other conditions ($p \leq .05$).

sEMG

Biceps Brachii

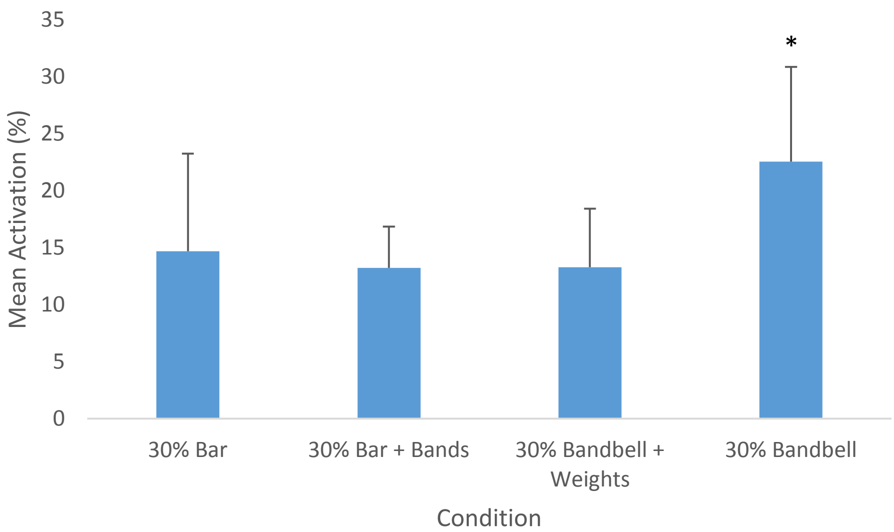

Figure 17: Mean (± SD) biceps brachii mean activation during condition trials (* = p ≤ .05)

A repeated measures ANOVA determined that biceps brachii mean activation differed significantly between loading conditions ($F(3, 33) = 7.83$, $P = .001$). Post hoc tests using the Bonferroni correction revealed that mean activation during the 30% Bandbell trial was significantly greater than any of the other conditions ($p \leq .05$).

Triceps Brachii

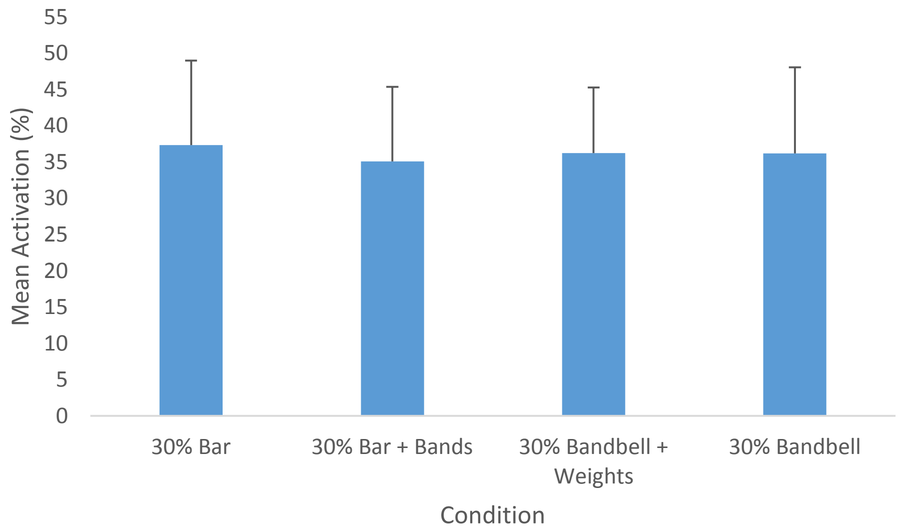

Figure 18: Mean (± SD) triceps brachii mean activation during condition trials

A repeated measures ANOVA determined that triceps brachii mean activation did not differ significantly between loading conditions ($F(3, 30) = 9.43$, $P = .385$).

Pectoralis Major

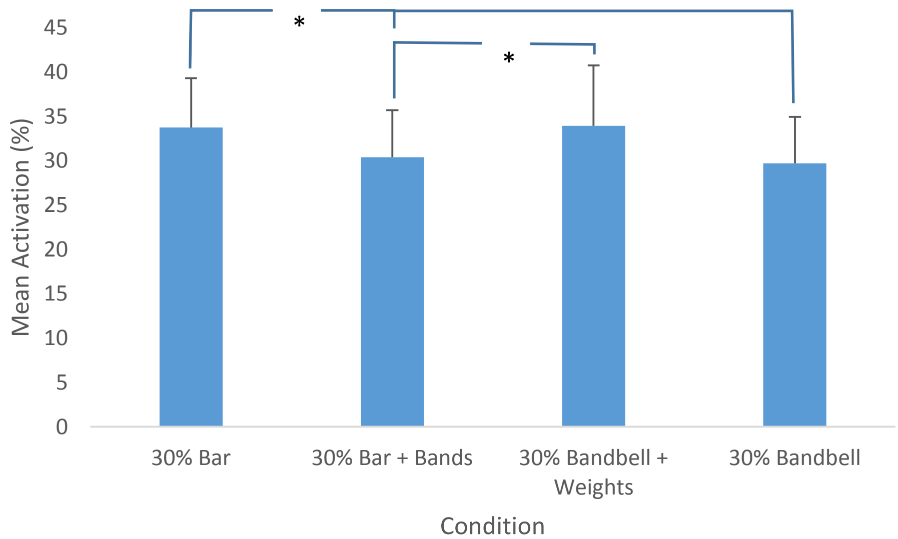

Figure 19: Mean (± SD) pectoralis major mean activation during condition trials (* = p ≤ .05)

A repeated measures ANOVA determined that pectoralis major mean activation differed significantly between loading conditions ($F(3, 30) = 7.08$, $P = .001$). Post hoc tests using the Bonferroni correction revealed that pectoralis major mean activation during the 30% Bar trial was significantly greater than both the 30% Bar and Bands and 30% Bandbell trials ($p \leq .05$). Also, mean activation during the 30% Bandbell and Weights trial was significantly greater than during the 30% Bar and Bands trial ($p \leq .05$).

Anterior Deltoid

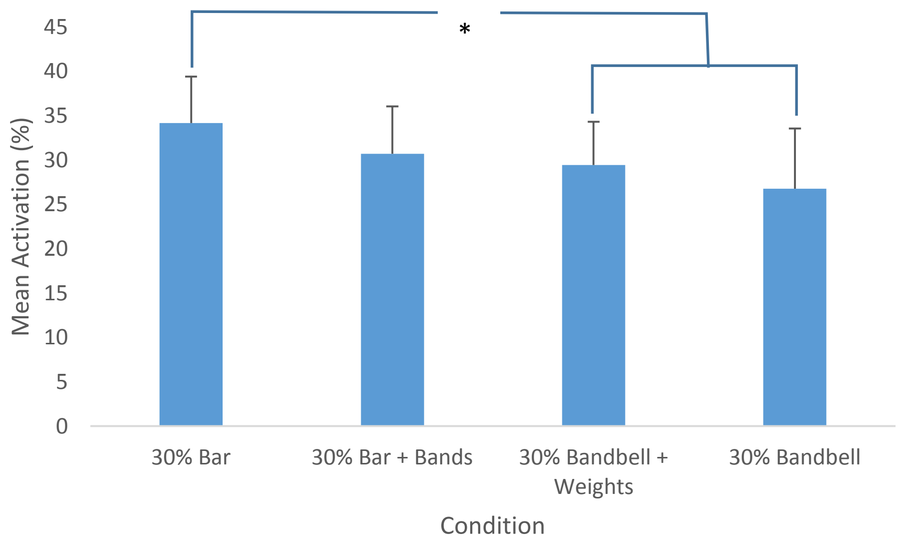

Figure 20: Mean (± SD) anterior deltoid mean activation during different condition trials (* = p ≤ .05)

A repeated measures ANOVA with a Greenhouse-Geisser correction determined that anterior deltoid mean activation differed significantly between loading conditions ($F(1.67, 16.68) = 7.44$, $P = .007$). Post hoc tests using the Bonferroni correction revealed that anterior deltoid mean activation was significantly greater during the 30% Bar trial than the 30% Bandbell and Weights and 30% Bandbell trials ($p \leq .05$).

Latisimus Dorsii

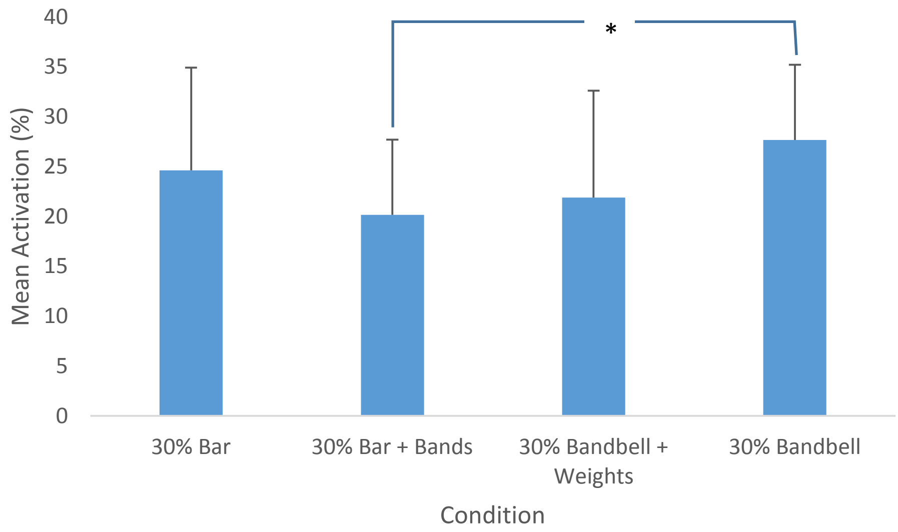

Figure 21: Mean (± SD) latisimus dorsii mean activation during condition trials (* = p ≤ .05)

A repeated measures ANOVA determined that latisimus dorsii mean activation differed significantly between loading conditions ($F(3, 30) = 2.983$, $P = .047$). Post hoc tests using the Bonferroni correction revealed that latisimus dorsii mean activation during the 30% Bandbell trial was significantly greater than the 30% Bar and Bands trial ($p \leq .05$).

External Oblique

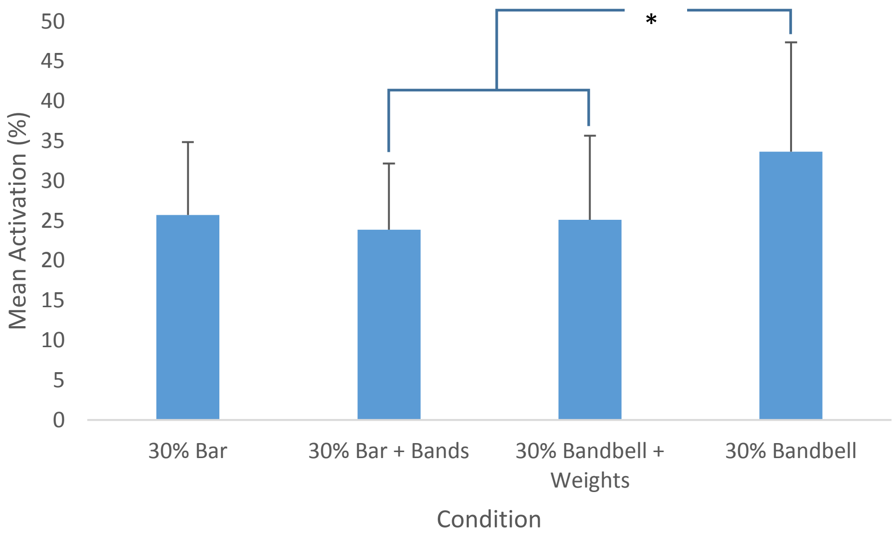

Figure 22: Mean (± SD) external oblique mean activation during condition trials (* = p ≤ .05)

A repeated measures ANOVA with a Greenhouse-Geisser correction determined that external oblique mean activation differed significantly between loading conditions ($F(1.83, 18.30) = 6.47$, $P = .009$). Post hoc tests using the Bonferroni correction revealed that external oblique mean activation was significantly greater during the 30% Bandbell trial than the 30% Bar and Bands and 30% Bandbell and Weights trials ($p \leq .05$).

Vastus Lateralis

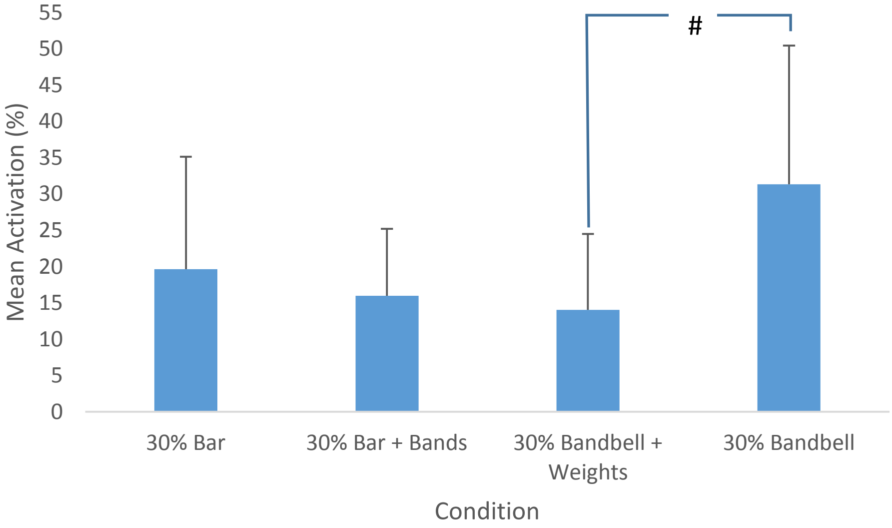

Figure 23: Mean (± SD) vastus lateralis mean activation during condition trials (# = p ≤ .10)

A repeated measures ANOVA with a Greenhouse-Geisser correction determined that vastus lateralis mean activation differed significantly between loading conditions ($F(1.61, 16.12) = 5.16$, $P = .024$). Post hoc tests using the Bonferroni correction revealed that vastus lateralis mean activation between the 30% Bandbell and Weights and 30% Bandbell conditions was approaching significance ($p = .073$).

Gastrocnemius

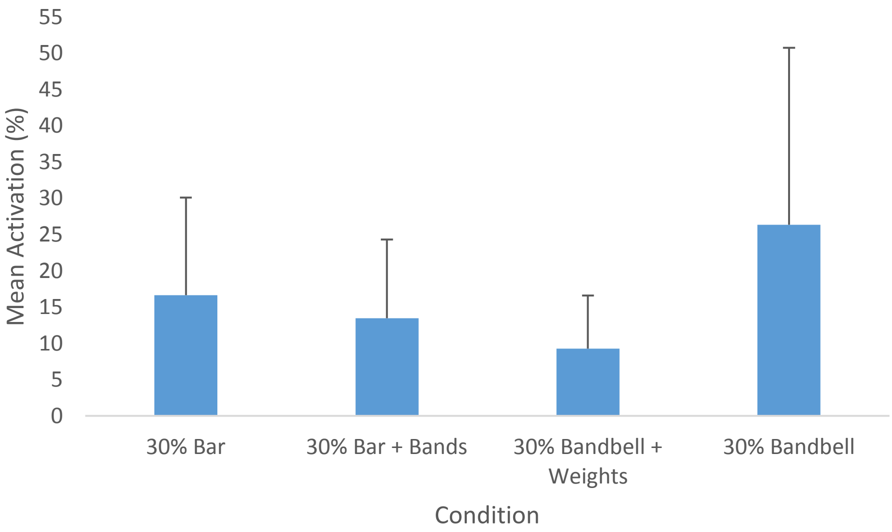

Figure 24: Mean (± SD) gastrocnemius mean activation during condition trials

A repeated measures ANOVA with a Greenhouse-Geisser correction determined that gastrocnemius mean activation did not differ significantly between loading conditions ($F(1.58, 15.78) = 2.54$, $P = .119$).

Chapter 6 - Discussion

Proponents of instability resistance training claim that unstable training modalities stress the neuromuscular system to a greater extent than more stable strength training exercises (Behm and Anderson, 2006). To the authors knowledge this is the first study to investigate the BandBell, with the aim of determining if the BandBell bench press elicited a greater muscle activation than the standard bench press at a given relative load.

It was found that the distance travelled in the sagittal and transverse planes was significantly greater with the Bandbell at all intensities. This indicates the Bandbell produced more instability than the bar and resulted in greater mean activation of the biceps brachii and external obliques. Distance travelled in the sagittal and transverse planes and mean activation of the biceps brachii were significantly greater for the Bandbell condition and therefore it is likely that the mass and function of the Bandbell (30% Bandbell > 30% Bar, 30% Bar and Bands, 30% Bandbell and Weight) was causative of this.

These findings are in agreement with those of Schick *et al.* (2010) and Saeterbakken, Van Der Tillaar and Fimland (2011). Schick *et al.* (2010) recorded muscle activation of the anterior deltoid, medial deltoid and pectoralis major, during smith machine and free weight bench press. 70% and 90% 1RM intensities were used for each exercise and two repetitions were performed at both whilst EMG data was recorded. The main finding was that the activation of the medial deltoid was significantly higher (approximately 160%) during the free weight bench press. They concluded that the instability caused by the free weight bench press necessitates a greater response by the medial deltoid as both a force producer and perhaps more importantly as a stabiliser. However, there was no significant difference between stability conditions in the activation of the anterior deltoid or pectoralis major. This is likely due to the fact that they are prime movers as opposed to stabilisers and therefore are mostly unaffected by instability. Saeterbakken, Van Der Tillaar and Fimland (2011) compared 1RM and muscle activity in three “chest-press” exercises with different stability requirements – smith machine bench press, barbell bench press and dumbbell bench press. EMG activity of the PM, AD, BB and TB were recorded. The dumbbell load was 14% less than for the smith machine and 17% less than that for the barbell bench press. The barbell bench press load was approximately 3% higher than the smith machine. EMG activity of the PM and AD did not differ between conditions. BB activation increased with increasing stability requirements (dumbbell bench press>barbell bench press>smith machine bench press). TB activity was reduced using dumbbells when compared to barbell and smith machine bench press. These findings are similar to those of the current study in that increasing biceps brachii activation was found with increasing instability and again, just as in Schick *et al.* (2010), the prime movers: pectoralis major and anterior deltoid did not differ significantly between stability conditions. However, with regards to triceps brachii activity, the use of dumbbells to elicit instability appears to significantly reduce activation, however, in the current study this was not observed. This may have been due to maintaining the same degrees of freedom and movement pattern as in the bench press, but with instability applied to that specific movement. Consequently triceps brachii activity was maintained. The finding that the EMG activity of the anterior deltoid was relatively consistent across conditions may be explained by the fact that it also functions as a glenohumeral stabiliser (Kohler, Flanagan and Whiting, 2010). Increased muscle activity may be necessary to stabilise the glenohumeral joint. The increase in activity required for stabilization may have offset the decrease in activity that would be expected with a decreased load, resulting in the same level of activation between conditions.

Neither Schick *et al.* (2010) or Saeterbakken, Van Der Tillaar and Fimland (2011) examined any of the "core" musculature beyond the shoulder girdle. This may have been because of the assumption that if using a bench, nothing beyond the shoulder girdle is active. This could not be further from the truth if the bench press is being performed correctly as a lift for developing maximal strength as in powerlifting. The whole body should be rigid and the core and lower limbs tensed. The external obliques play an important role in stabilising the spine. The abdominal muscles work together to increase spinal stability and the rectus abdominis transmits the lateral force from the obliques to form a continuous loop of tension around the abdomen. Studies using unstable surfaces, such as Norwood *et al.* (2007) tend to concentrate more on this musculature (exclusively in this case), however, as evidenced in this current study the "core" is still very active when an unstable load is used on a stable surface. Activation of the external obliques was higher with the BandBell, when compared to both BandBell and ankle weights and barbell and bands at 30% 10RM, however it was not significantly different to the barbell condition.

Applications of the current study may be in injury prevention and rehabilitation. Despite the popularity of the bench press, it has been demonised somewhat and reputed to cause injury of the shoulder girdle and the muscles that surround it. Durrall, Manske and Davies (2001) state that injuries to the shoulder are relatively common among weight trainers and can be career-threatening to those at the competitive level. Fortunately, most shoulder injuries from resistance training are minor musculo-tendonous strains or ligamentous-capsular sprains. However, when improper exercises or exercise techniques are utilized, resistance training may exacerbate or contribute to the development of glenohumeral joint hyperlaxity, instability or impingement. When the static glenohumeral ligamentous-capsular restraints are excessively lax or unstable, the dynamic rotator cuff muscles are thought to exert greater force to stabilize the humeral head. This dynamic compensation often results in fatigue followed by rotator cuff tendonitis and pain.

The bench press presents several problems for the lifter; the musculoskeletal system of the shoulder girdle has to provide a base of support for the motion of the barbell from and to the chest. Elbow flexors and horizontal flexors in the shoulder act alternately in concentric and eccentric contractions. Thus despite the bench press being a very popular exercise, due to incorrect technique, individuals are at risk from acute shoulder injuries involving a sudden traumatic episode, such as ruptures of the pectoralis major (Wolfe, Wickiewicz and Cavanaugh,1992; Green and Comfort, 2007). The musculoskeletal system of the glenohumeral joint has to provide a base of support for the motion of the barbell during the bench press. The bench press action may place the glenohumeral joint in a position approaching ninety degrees of abduction and the position may include some external rotation. Ninety degrees of abduction, combined with end-range external rotation has been defined as the “at-risk position” that may increase the risk of shoulder injuries (Green and Comfort, 2007). It has been reported that a hand spacing of ≥ 2 biacromial width (shoulder width as defined by the distance between the acromion processes) increases shoulder abduction above seventy five degrees, wheras hand spacing ≤1.5 biacromial width maintains shoulder abduction below forty five degrees (Green and Comfort, 2007).

As powerlifters regularly train using the bench press exercise, they are an ideal population to investigate for associated injury incidence. Keogh, Hume and Pearson (2006) stated that powerlifting is a sport in which the stresses applied to the musculoskeletal system of the body when the lifter is performing the squat, bench press and deadlift exercises can be immense. Some members of the public, sporting, medical and scientific communities often state that powerliftng is an inherently dangerous sport that would result in numerous serious or long term injuries. Powerlifters suffer a relatively low number of injuries during the course of a year and the majority of these injuries are of minor or moderate severity in terms of their effect on subsequent training. One consideration is that in order to lift such immense loads, powerlifters must generate exceedingly large musculoskeletal forces and torques and may therefore be susceptible to a range of musculoskeletal injuries (Keogh, Hume and Pearson, 2006). The authors found that on average, each powerlifter obtained just over one injury per year (4 injuries per 1000 hours of training), with the most frequently injured body regions being the shoulder (36%) and lower back (24%). The proportionally higher rate of shoulder injuries may be a result of the higher stresses the bench press applies to the shoulder, particularly the rotator cuff, acromioclavicular joint and shoulder capsule. The authors found that the majority of the injuries were caused by the three power lifts (52%) or assistance exercises (20%). These results indicate that the injuries suffered by powerlifters cannot all be attributed to one particular exercise, such as the bench press. Raske and Norlin (2002) also found no significant difference in the incidence of shoulder injuries in power lifters based on the upper body exercises they routinely performed in training (such as the bench press).

Raske and Norlin (2002) hypothesised that the bench press is a critical event for the shoulder among the powerlifting events because the shoulder girdle must provide a stable base of support for the lifting motion of the barbell. The shoulder muscles have to alternate between maximal concentric and eccentric contraction when stabilizing, lifting or lowering the barbell. Proper technique, including muscle stretching and a throughout warm-up together with a training schedule that will spread out exercises that stress one muscle group over the week, seems to be important for competitive lifters to prevent injury.

It is interesting however that national level competitors had significantly more chest and shoulder injuries than international competitors. This seems consistent with the finding that the bench press was responsible for a greater proportion of injuries and was more frequently affected by injury in national than in the international lifters. These results indicate that in order to reduce their proportionally higher rates of shoulder and chest injuries, national lifters may need to alter the manner in which they train the upper-body. They may need to pay more attention to bench press technique, bench press training program variables (e.g.: warm-up procedures, training volume and intensity) and address upper body muscular and range-of-motion imbalances and deficits. Shoulder injury was the most common injury amongst powerlifters. The rate of shoulder injuries per 1000 hours of powerlifting activity was found to be 0.61. The average number of hours training per week was 8.94, which equates to 465 hours of training per year. Therefore an injury is likely to occur on average every 3.53 years (Raske and Norlin, 2002).

One drawback with instability training is that several studies have found decreases in force production such as Koshida *et al.* (2008), who found significant decreases (reduction rates) in power (9.9% ± 11.5), force (5.9% ± 5.7) and velocity (9.1% ± 10) when comparing single bench press repetitions (50% 1RM) performed on a Swiss ball to a bench. Integrating a balance factor into a strength training program may not provide an adequate overload necessary for muscle hypertrophy and strength gains. Consequently, the effectiveness of instability training is contingent on the specific training goal. If an athlete’s aim is to increased strength outside the core, such as in the competitive bench press, then it has been demonstrated that performing resistance training exercises solely in an unstable environment would be detrimental to strength gains. The inclusion of resistance training with more stable surfaces would be necessary to reach training intensities required to develop maximal strength (≥85% 1RM) (Anderson and Behm, 2004). Thus, maximal effort work should be maintained as normal and instability training should be used during assistance repeated effort work.

Some of the possible limitations of the current study are mainly surrounding the small sample size and the nature of the exercise. The sample size was likely too small to provide clear data. This combined with the "chaotic" nature of the exercise and participants varying degrees of pre-existing stability resulted in non-normally distributed data. With a slightly larger sample size, many of the tendencies that are present in the data would likely show significance. It is acknowledged there may have been an order effect of the trials.

For future work the inclusion of kinematic analysis would be beneficial for monitoring the bar path as well as the joint angles of the subject. Another area to consider may be the body mass and composition of participants relative to their bench press strength. It has been noted anecdotally that the lower the relative strength then the more inherently stable a participant will be because of the favourable ratio of body mass to bench press mass. A training study may also be advisable to monitor whether the relatively low loads (20-40% 10RM) elicit any favourable training effect.

Conclusion

In conclusion, this study shows that the Bandbell is successful at inducing instability during the bench press and produces greater mean activation in stabilising musculature.

References

Anderson, K.G., Behm, D.G. (2004) Maintenance of EMG activity and loss of force output with instability. *Journal of Strength and Conditioning Research*, 18: 637-640.

Baechle, T.R., Earle, R.W. (2008) *Essentials of Strength Training and Conditioning.* 3rd ed. Human Kinetics: Champaign, IL, USA.

Behm, D.G., Anderson, K.G. (2006) The Role of Instability With Resistance Training. *Journal of Strength and Conditioning Research*, 20 (3): 716-722.

Behm, D.G., Sanchez, J.C.C. (2013) Instability Resistance Training Across the Exercise Continuum. *Sports Health: A Multidisciplinary Approach*, 5 (6): 500-503

Bigland-Ritchie, B., Kukulka, C.G., Woods, J.J. (1980) Surface EMG/force relation in human muscle of different fibre composition. *Journal of Physiology*, 308: 103-4

Bigland-Ritchie, B., Lippold, O.C. (1954) The relation between force, velocity and integrated electrical activity in human muscles. *Journal of Physiology*, 123(1): 214-24

Burden, A., Bartlett, R. (1999) Normalisation of EMG amplitude: an evaluation and comparison of old and new methods. *Medical Engineering and Physics*, 21: 247-257

Cobb, S., Forbes, A. (1923) Electromyographic studies of muscle fatigue in man. *American Journal of Physiology*, 65: 234-251

Clamann, H.P., Broeker, K.T. (1979) Relation between force and fatigability of red and pale skeletal muscles in man. *American Journal of Physical Medicine*, 58: 70-85

Clarys, J.P. (2000) Electromyography in sports and occupational settings: an update of its limits and possibilities. *Ergonomics,* 43 (10): 1750-62.

De Luca, C.J. (1997) The use of electromyography in biomechanics. *Journal of Applied Biomechanics*, 13: 135-163

Durall, C.J., Manske, R.C., Davies, G.J. (2001) Avoiding Shoulder Injury From Resistance Training. *Strength and Conditioning Journal*, 23 (5): 10-18.

Goodman, C.A., Pearce, A.J., Nicholes, C.J., Gatt, B.M., Fairweather, I.H. (2008) No Difference in 1RM Strength and Muscle Activation During the Barbell Chest Press on a Stable and Unstable Surface. *Journal of Strength and Conditioning Research*, 22 (1): 88-94.

Green, C.M., Comfort, P. (2007) The Affect of Grip Width on Bench Press Performance and Risk of Injury. *Strength and Conditioning Journal,* 29 (5): 10-14.

Hermens, H.J., Freriks, B., Disselhorst-Klug, C., Rau, G. (2000) Development of recommendations for SEMG sensors and sensor placement procedures. *Journal of Electromyography and Kinesiology,* 10: 361-374.

Kamen, G., Caldwell, G.E. (1996) Physiology and Interpretation of the electromyogram. *Journal of Clinical Neurophysiology*, 13(5): 366-384

Keogh, J., Hume, P.A., Pearson, S. (2006) Retrospective Injury Epidemiology of One Hundred One Competitive Oceania Power Lifters: The Effects of Age, Body Mass, Competitive Standard and Gender. *Journal of Strength and Conditioning Research,* 20 (3): 672-681.

Kohler, J.M., Flanagan, S.P., Whiting, W.C. (2010) Muscle Activation Patterns While Lifting Stable and Unstable Loads on Stable and Unstable Surfaces. *Journal of Strength and Conditioning Research*, 24 (2): 313-321.

Komi, P.V., Buskirk, E.R. (1972) Effects of eccentric and concentric muscle conditioning on tension and electrical activity of human muscle. *Ergonomics*, 15: 417-434

Koshida, S., Urabe, Y., Miyashita, K., Iwai, K., Kagimori, A. (2008) Muscular Outputs During Dynamic Bench Press Under Stable Versus Unstable Conditions. *Journal of Strength and Conditioning Research*, 22 (5): 1584-1588.

Lippold, O.C. (1952) The relation between integrated action potentials in a human muscle and its isometric tension. *Journal of Physiology*, 117 (4): 492-9

Madsen, N., McLaughlin, T (1984) Kinematic factors influencing performance and injury risk in the bench press exercise. *Medicine and Science in Sports and Exercise,* 16(4): 376-381

McCaw, S.T., Friday, J.J. (1994) A comparison of muscle activity between free weight and machine bench press. *Journal of Strength and Conditioning Research,* 8: 259-264.

Marshall, P.W.M., Murphy, B.A. (2006) Increased Deltoid and Abdominal Muscle Activity During Swiss Ball Bench Press. *Journal of Strength and Conditioning Research,* 20 (4): 745-750.

Norwood, J., Anderson, G.S., Gaetz, M, Twist, P. (2007) Electromyographic Activity of the Trunk Stabilisers During Stable and Unstable Bench Press. *Journal of Strength and Conditioning Research,* 21 (2): 343-347.

Osgawara, R., Loenneke, J.P., Thiebaud, R.S., Abe, T. (2013) Low-Load Bench Press Training to Fatigue Results in Muscle Hypertrophy Similar to High-Load Bench Press Training. *International Journal of Clinical Medicine,* 4: 114-121.

Piper, H.E. (1912) Electrophysiologie Menschlichen Muskeln Springer. Berlin, Germany

Raske, A., Norlin, R. (2002) Injury Incidence and Prevalence among Elite Weight and Power Lifters. *The American Journal of Sports Medicine,* 30 (2): 248-256.

Rippetoe, C.M., Kilgore, J.L. (2009) *Practical Programming for Strength Training*. 2nd ed. The Aasgaard Company Publishers: Wichita Falls, TX, USA.

Rutherford, O.M., Jones, D.A. (1986) The role of learning and coordination in strength training. *European Journal of Applied Physiology,* 55: 100-105.

Saeterbakken, A.H., Van Den Tillaar, R.V., Fimland, M.S. (2011) A comparison of muscle activity and 1-RM strength of three chest-press exercises with different stability requirements. *Journal of Sports Sciences,* 29 (5): 533-538.

Schick, E.E., Coburn, J.W., Brown, L.E., Judelson, D.A., Khamoui, A.V., Tran, T.T., Uribe, B.P. (2010) A Comparison of Muscle Activation Between a Smith Machine and Free Weight Bench Press. *Journal of Strength and Conditioning Research,* 24 (3): 779-784.

Sharma, R., Singh Viij, J. (2005) Occurance of Bicipital Tendonitis/Rotator Cuff Tendonitis in the Subjects involved in Bench Press Activities in the Gymnasium. *Journal of Exercise Science and Physiotherapy,* 1(1&2):85-88.

Sodberg, G.L., Knutson, L.M. (2000) A Guide for the Use and Interpretation of Kinesiologic Electromyographic Data. *Physical Therapy,* 80(5): 485-498.

Uribe, B.P., Coburn, J.W., Brown, L.E., Judelson, D.A., Khamoui, A.V., Nguyen, D. (2010) Muscle Activation When Performing the Chest Press and Shoulder Press on a Stable Bench vs. a Swiss Ball. *Journal of Strength and Conditioning Research,* 24 (4): 1028-1033.

Verhagen, E.A.L.M., van Tulder, M., van der Beek, A.J., van Mechelen, W. (2004) An economic evaluation of a proprioceptive balance board training programme for the prevention of ankle sprains in volleyball. *British Journal of Sports Medicine,* 39: 111-115.

Welsch, E.A., Bird, M., Mayhew, J.L. (2005) Electromyographic activity of the pectoralis major and anterior deltoid muscles during three upper-body lifts. *Journal of Strength and Conditioning Research*, 19: 449-452.

Wilson, G.J., Elliott, B.C., Kerr, G.K. (1989) Bar path and force profile characteristics for maximal and submaximal loads in the bench press. *International Journal of Sport Biomechanics*, 5: 391-402

Wilson, G.J., Elliott, B.C., Wood, G.A. (1991) The effect on performance of imposing a delay during a stretch-shorten cycle movement. *Medicine and Science in Sport and Exercise*, 23(3): 364-369

Wolfe, S.W., Wickiewicz, T.L., Cavanaugh, J.T. (1992) Ruptures of the pectoralis major muscle. An anatomic and clinical analysis. *American Journal of Sports Medicine,* 20: 587-593.

Yang, Winter, D. (1984) Electromyographic amplitude normalization methods: Improving their sensitivity as diagnostic tools in gait analysis. *Archives of Physical Medical Rehabilitation*, 65(9): 517-52

School of Psychology RISK ASSESSMENT FORM (Medium & High Risk, Student Version)

Use this form to risk-assess:

- *Off-campus student activities (research, fieldwork, educational visits etc) in medium/high risk environments such as factories, farms, prisons, remote areas or participants' homes.*
- *All student activities involving medium/high risk procedures or use of specialist equipment.*

For low risk locations and activities, use the appropriate low risk form.

This form should be completed by the staff member responsible for the activity (e.g. the project supervisor), in consultation with the student and a qualified or otherwise competent person (normally a technician or Faculty HSE officer). Completed forms must be countersigned by the Head of School or the Chair of the School Health & Safety Committee.

Student:	**Assessment Undertaken By:** (Staff member)	**Assessment Verified By:** (Technician or other competent person)
Name: Ben Staniforth	Name: Dr. Chris Edmundson	Name:
Signed:	Signed:	Signed:
Date:	Date:	Date*:
Note: Risk Assessment is valid for **one year from the date given above. Risk Assessments for activities lasting longer than one year should be reviewed annually.*		
Countersigned by Head of School or Chair of H&S Committee:		

Date:

Risk Assessment For:
Activity: Barbell/Bandbell Bench Press
Location of Activity: Biomechanics Laboratory

Page 1 of 2

List significant hazards here:	**List groups of people who are at risk:**	**List existing controls, or refer to safety procedures etc:**	**For risks which are not adequately controlled, list the action needed:**	**Remaining level of risk (high, medium or low):**
Injury Bar Flipping Out of Rack whilst Loading Loss of Consciousness during 10RM test	Previously Injured/Poor Technique Loaders/Spotters	PAR-Q/Technique Coaching Awareness of how to load the bandbell		

Continue on another sheet if necessary.

Page 2 of 2

Participant Information

A Comparison of the standard Barbell and novel Bandbell Bench Press

What is the purpose of this study?

The purpose of this study is to compare the novel bandbell bench press to the standard bench press. The bandbell is thought to increase shoulder stability and bench press technique with continued use. It is thought to do this through the instability it generates, causing more of the body's musculature to activate to stabilise the bar. The activation of the musculature can be measured using sensors placed on the skin through a system known as Electromyography (EMG). Force plates mounted in the floor will also measure forces applied through the feet to approximate how hard you are working to stabilise. Therefore, with your help the aim of this study is to determine if the bandbell bench press results in higher muscle activation and body bracing for a given load, when compared to the standard barbell bench.

What do I have to do?

If you would like to volunteer for the study all we ask is that you attend three sessions, each spaced one week apart, in the biomechanics laboratory in Darwin Building at UCLan. Each visit will last approximately one hour. During the initial session your height and weight will be measured and you will be familiarised with the testing equipment, you will then be taken through an incremental protocol to establish your standard bench press 10 repetition maximum.

The second and third visit to the labs will involve you undertaking an incremental protocol with either a standard barbell or novel bandbell using fixed loads ranging from 22.5kg up to a maximum of 92.5kg for 10 repetitions.

Throughout the exercise your muscular activation will be monitored using multiple sensors attached to the skin above different muscles. There may be a requirement to shave some areas to allow the sensors to maintain good contact with the skin. Also the forces you exert through your feet will be measured.

<u>What will I gain from participating in the study?</u>

There will be no financial reward from taking part in this study, however, you will have access to the end group results of the study.

As a participant in this study, it is important that you are aware that your results are strictly confidential. Individual data will not be presented and results will be anonymous when used for published work.

You are free to withdraw from the study at any time up to 24 hours after laboratory testing. After this it will be impossible to remove individual data as it will have been made anonymous. If you wish to withdraw please contact myself or Chris.

If you have any further questions, please feel free to contact either myself or Chris:

Researcher

Ben Staniforth BStaniforth@uclan.ac.uk

CASES,

DB255, Darwin Building, 07505 104363

UCLan,

Preston,

Lancashire,

PR1 2HE

Director of Studies

Dr. Chris Edmundson CJEdmundson@uclan.ac.uk

CASES,

DB204, Darwin Building, 01772 893317

UCLan,

Preston,

Lancashire,

PR1 2HE

University of Central Lancashire

School of Psychology

Informed Consent Form

Investigation:

Investigator:

Participant No.

Name ____

I have read the attached information sheet and discussed the project with the investigator. The nature, demands and the risks associated with the project have been explained to me. I knowingly accept the risks involved and feel confident that I can undertake the requirements of the test without undue strain. As such I agree to participate in the above named study. I understand that I may withdraw my consent and discontinue participation at any time without having to give an explanation.

Participant's signature:

____

I certify that I have explained to the above individual the nature, purpose and possible risks associated with participation in this research study, have answered any questions that have been raised, and have witnessed the above signature

Signature of investigator :

____

Date _____________

Biceps

T-Test

Notes

Output Created		28-OCT-2013 19:14:02
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	11
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	Statistics for each analysis are based on the cases with no missing or out-of-range data for any variable in the analysis.

Syntax		T-TEST PAIRS=bar20 bar30 bar40 WITH band20 bandbell30 bandbell40 (PAIRED) /CRITERIA=CI(.9500) /MISSING=ANALYSIS.
Resources	Processor Time	00:00:00.02
	Elapsed Time	00:00:00.02

[DataSet0]

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	bar20	8.2422	11	2.99362	.90261
	band20	13.3967	11	3.98156	1.20049
Pair 2	bar30	14.6856	11	8.55866	2.58053
	bandbell30	22.5543	11	8.31314	2.50651
Pair 3	bar40	17.8958	11	7.61612	2.29635
	bandbell40	31.5980	11	11.58965	3.49441

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	bar20 & band20	11	.430	.187
Pair 2	bar30 & bandbell30	11	.562	.072
Pair 3	bar40 & bandbell40	11	-.218	.520

Paired Samples Test

		Paired Differences						
					95% Confidence Interval of the Difference			
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df
Pair 1	bar20 - band20	-5.15447	3.81608	1.15059	-7.71815	-2.59079	-4.480	10
Pair 2	bar30 - bandbell30	-7.86876	7.89767	2.38124	-13.17449	-2.56303	-3.304	10
Pair 3	bar40 - bandbell40	-13.70218	15.18986	4.57992	-23.90687	-3.49749	-2.992	10

```
GLM bar30 barandbands30 bandbellandweight30 bandbell30
  /WSFACTOR=factor1 4 Polynomial
  /MEASURE=activation
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(factor1) COMPARE ADJ(BONFERRONI)
  /PRINT=DESCRIPTIVE ETASQ
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=factor1.
```

General Linear Model

Notes

Output Created		28-OCT-2013 19:15:19
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	11

Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax		GLM bar30 barandbands30 bandbellandweight30 bandbell30 /WSFACTOR=factor1 4 Polynomial /MEASURE=activation /METHOD=SSTYPE(3) /EMMEANS=TABLES(factor1) COMPARE ADJ(BONFERRONI) /PRINT=DESCRIPTIVE ETASQ /CRITERIA=ALPHA(.05) /WSDESIGN=factor1.
Resources	Processor Time	00:00:00.05
	Elapsed Time	00:00:00.06

[DataSet0]

Within-Subjects Factors

Measure: activation

factor1	Dependent Variable

1	bar30
2	barandbands30
3	bandbellandweight30
4	bandbell30

Descriptive Statistics

	Mean	Std. Deviation	N
bar30	14.6856	8.55866	11
barandbands30	13.2445	3.62360	11
bandbellandweight30	13.3030	5.12593	11
bandbell30	22.5543	8.31314	11

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
factor1	Pillai's Trace	.593	3.879[b]	3.000	8.000	.056	.593
	Wilks' Lambda	.407	3.879[b]	3.000	8.000	.056	.593
	Hotelling's Trace	1.455	3.879[b]	3.000	8.000	.056	.593
	Roy's Largest Root	1.455	3.879[b]	3.000	8.000	.056	.593

a. Design: Intercept
Within Subjects Design: factor1

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: activation

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]

					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
factor1	.386	8.293	5	.143	.702	.894	.333

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: factor1

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: activation

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
factor1	Sphericity Assumed	654.961	3	218.320	7.829	.001	.439
	Greenhouse-Geisser	654.961	2.106	310.993	7.829	.003	.439
	Huynh-Feldt	654.961	2.681	244.267	7.829	.001	.439
	Lower-bound	654.961	1.000	654.961	7.829	.019	.439
Error(factor1)	Sphericity Assumed	836.616	30	27.887			
	Greenhouse-Geisser	836.616	21.060	39.725			
	Huynh-Feldt	836.616	26.813	31.201			
	Lower-bound	836.616	10.000	83.662			

Tests of Within-Subjects Contrasts

Measure: activation

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
factor1	Linear	308.011	1	308.011	10.819	.008	.520
	Quadratic	314.397	1	314.397	6.805	.026	.405

	Cubic	32.553	1	32.553	3.620	.086	.266
Error(factor1)	Linear	284.699	10	28.470			
	Quadratic	461.983	10	46.198			
	Cubic	89.934	10	8.993			

Tests of Between-Subjects Effects

Measure: activation
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	11189.322	1	11189.322	114.057	.000	.919
Error	981.031	10	98.103			

Estimated Marginal Means

factor1

Estimates

Measure: activation

factor1	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	14.686	2.581	8.936	20.435
2	13.245	1.093	10.810	15.679
3	13.303	1.546	9.859	16.747
4	22.554	2.507	16.969	28.139

Pairwise Comparisons

Measure: activation

(I) factor1		Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	1.441	2.117	1.000	-5.497	8.379
	3	1.383	2.229	1.000	-5.922	8.687
	4	-7.869*	2.381	.048	-15.672	-.066
2	1	-1.441	2.117	1.000	-8.379	5.497
	3	-.058	1.068	1.000	-3.559	3.442
	4	-9.310*	2.602	.030	-17.835	-.785
3	1	-1.383	2.229	1.000	-8.687	5.922
	2	.058	1.068	1.000	-3.442	3.559
	4	-9.251*	2.719	.040	-18.160	-.343
4	1	7.869*	2.381	.048	.066	15.672
	2	9.310*	2.602	.030	.785	17.835
	3	9.251*	2.719	.040	.343	18.160

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	.593	3.879[a]	3.000	8.000	.056	.593
Wilks' lambda	.407	3.879[a]	3.000	8.000	.056	.593
Hotelling's trace	1.455	3.879[a]	3.000	8.000	.056	.593
Roy's largest root	1.455	3.879[a]	3.000	8.000	.056	.593

Each F tests the multivariate effect of factor1. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

```
T-TEST PAIRS=bar20 bar30 bar40 WITH band20 bandbell30 bandbell40 (PAIRED)
  /CRITERIA=CI(.9500)
  /MISSING=ANALYSIS.
```

Triceps

T-Test

Notes

Output Created		28-OCT-2013 19:19:42
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	11
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	Statistics for each analysis are based on the cases with no missing or out-of-range data for any variable in the analysis.

Syntax		T-TEST PAIRS=bar20 bar30 bar40 WITH band20 bandbell30 bandbell40 (PAIRED) /CRITERIA=CI(.9500) /MISSING=ANALYSIS.
Resources	Processor Time	00:00:00.02
	Elapsed Time	00:00:00.01

```
[DataSet0]
```

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	bar20	28.3090	11	10.49796	3.16525
	band20	27.3285	11	10.35386	3.12181
Pair 2	bar30	37.3579	11	11.62503	3.50508
	bandbell30	36.1771	11	11.89364	3.58607
Pair 3	bar40	41.8872	11	8.44410	2.54599
	bandbell40	41.9288	11	6.42507	1.93723

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	bar20 & band20	11	.919	.000
Pair 2	bar30 & bandbell30	11	.929	.000
Pair 3	bar40 & bandbell40	11	.677	.022

Paired Samples Test

		Paired Differences					t	df
					95% Confidence Interval of the Difference			
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper		
Pair 1	bar20 - band20	.98046	4.20365	1.26745	-1.84359	3.80451	.774	10
Pair 2	bar30 - bandbell30	1.18082	4.45108	1.34205	-1.80945	4.17109	.880	10
Pair 3	bar40 - bandbell40	-.04158	6.25245	1.88518	-4.24204	4.15887	-.022	10

```
GLM bar30 barandbands30 bandbellandweight30 bandbell30
  /WSFACTOR=factor1 4 Polynomial
  /MEASURE=activation
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(factor1) COMPARE ADJ(BONFERRONI)
  /PRINT=DESCRIPTIVE ETASQ
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=factor1.
```

General Linear Model

Notes

Output Created		28-OCT-2013 19:20:23
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	11

Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax		GLM bar30 barandbands30 bandbellandweight30 bandbell30 /WSFACTOR=factor1 4 Polynomial /MEASURE=activation /METHOD=SSTYPE(3) /EMMEANS=TABLES(factor1) COMPARE ADJ(BONFERRONI) /PRINT=DESCRIPTIVE ETASQ /CRITERIA=ALPHA(.05) /WSDESIGN=factor1.
Resources	Processor Time	00:00:00.03
	Elapsed Time	00:00:00.10

[DataSet0]

Within-Subjects Factors

Measure: activation

factor1	Dependent Variable

1	bar30
2	barandbands30
3	bandbellandweight30
4	bandbell30

Descriptive Statistics

	Mean	Std. Deviation	N
bar30	37.3579	11.62503	11
barandbands30	35.0909	10.29836	11
bandbellandweight30	36.2555	9.03940	11
bandbell30	36.1771	11.89364	11

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
factor1	Pillai's Trace	.235	.817[b]	3.000	8.000	.520	.235
	Wilks' Lambda	.765	.817[b]	3.000	8.000	.520	.235
	Hotelling's Trace	.307	.817[b]	3.000	8.000	.520	.235
	Roy's Largest Root	.307	.817[b]	3.000	8.000	.520	.235

a. Design: Intercept
Within Subjects Design: factor1

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: activation

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]

					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
factor1	.923	.700	5	.983	.955	1.000	.333

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
 Within Subjects Design: factor1

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: activation

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
factor1	Sphericity Assumed	28.301	3	9.434	1.049	.385	.095
	Greenhouse-Geisser	28.301	2.864	9.880	1.049	.384	.095
	Huynh-Feldt	28.301	3.000	9.434	1.049	.385	.095
	Lower-bound	28.301	1.000	28.301	1.049	.330	.095
Error(factor1)	Sphericity Assumed	269.832	30	8.994			
	Greenhouse-Geisser	269.832	28.644	9.420			
	Huynh-Feldt	269.832	30.000	8.994			
	Lower-bound	269.832	10.000	26.983			

Tests of Within-Subjects Contrasts

Measure: activation

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
factor1	Linear	3.110	1	3.110	.351	.567	.034
	Quadratic	13.174	1	13.174	1.411	.262	.124

	Cubic	12.018	1	12.018	1.368	.269	.120
Error(factor1)	Linear	88.627	10	8.863			
	Quadratic	93.361	10	9.336			
	Cubic	87.844	10	8.784			

Tests of Between-Subjects Effects

Measure: activation
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	57724.219	1	57724.219	131.976	.000	.930
Error	4373.840	10	437.384			

Estimated Marginal Means

factor1

Estimates

Measure: activation

factor1	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	37.358	3.505	29.548	45.168
2	35.091	3.105	28.172	42.009
3	36.255	2.725	30.183	42.328
4	36.177	3.586	28.187	44.167

Pairwise Comparisons

Measure: activation

(I) factor1		Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	2.267	1.327	.710	-2.082	6.616
	3	1.102	1.348	1.000	-3.315	5.520
	4	1.181	1.342	1.000	-3.217	5.579
2	1	-2.267	1.327	.710	-6.616	2.082
	3	-1.165	1.186	1.000	-5.052	2.723
	4	-1.086	1.111	1.000	-4.726	2.553
3	1	-1.102	1.348	1.000	-5.520	3.315
	2	1.165	1.186	1.000	-2.723	5.052
	4	.078	1.338	1.000	-4.307	4.464
4	1	-1.181	1.342	1.000	-5.579	3.217
	2	1.086	1.111	1.000	-2.553	4.726
	3	-.078	1.338	1.000	-4.464	4.307

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	.235	.817[a]	3.000	8.000	.520	.235
Wilks' lambda	.765	.817[a]	3.000	8.000	.520	.235
Hotelling's trace	.307	.817[a]	3.000	8.000	.520	.235
Roy's largest root	.307	.817[a]	3.000	8.000	.520	.235

Each F tests the multivariate effect of factor1. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

```
T-TEST PAIRS=bar20 bar30 bar40 WITH band20 bandbell30 bandbell40 (PAIRED)
  /CRITERIA=CI(.9500)
  /MISSING=ANALYSIS.
```

Pecs

T-Test

Notes

Output Created		28-OCT-2013 19:21:11
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	11
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	Statistics for each analysis are based on the cases with no missing or out-of-range data for any variable in the analysis.

Syntax		T-TEST PAIRS=bar20 bar30 bar40 WITH band20 bandbell30 bandbell40 (PAIRED) /CRITERIA=CI(.9500) /MISSING=ANALYSIS.
Resources	Processor Time	00:00:00.02
	Elapsed Time	00:00:00.02

```
[DataSet0]
```

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	bar20	25.0617	11	5.90503	1.78043
	band20	22.1466	11	5.84197	1.76142
Pair 2	bar30	33.7651	11	5.55752	1.67566
	bandbell30	29.7177	11	5.22012	1.57392
Pair 3	bar40	41.0036	11	5.75860	1.73628
	bandbell40	38.0667	11	3.88629	1.17176

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	bar20 & band20	11	.679	.022
Pair 2	bar30 & bandbell30	11	.742	.009
Pair 3	bar40 & bandbell40	11	.595	.053

Paired Samples Test

		Paired Differences					t	df
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference			
					Lower	Upper		
Pair 1	bar20 - band20	2.91511	4.70804	1.41953	-.24780	6.07801	2.054	10
Pair 2	bar30 - bandbell30	4.04740	3.88231	1.17056	1.43923	6.65557	3.458	10
Pair 3	bar40 - bandbell40	2.93685	4.64925	1.40180	-.18656	6.06026	2.095	10

```
GLM bar30 barandbands30 bandbellandweight30 bandbell30
  /WSFACTOR=factor1 4 Polynomial
  /MEASURE=activation
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(factor1) COMPARE ADJ(BONFERRONI)
  /PRINT=DESCRIPTIVE ETASQ
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=factor1.
```

General Linear Model

Notes

Output Created		28-OCT-2013 19:21:47
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	11

Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax		GLM bar30 barandbands30 bandbellandweight30 bandbell30 /WSFACTOR=factor1 4 Polynomial /MEASURE=activation /METHOD=SSTYPE(3) /EMMEANS=TABLES(factor1) COMPARE ADJ(BONFERRONI) /PRINT=DESCRIPTIVE ETASQ /CRITERIA=ALPHA(.05) /WSDESIGN=factor1.
Resources	Processor Time	00:00:00.03
	Elapsed Time	00:00:00.06

[DataSet0]

Within-Subjects Factors

Measure: activation

factor1	Dependent Variable

1	bar30
2	barandbands30
3	bandbellandweight30
4	bandbell30

Descriptive Statistics

	Mean	Std. Deviation	N
bar30	33.7651	5.55752	11
barandbands30	30.4090	5.30790	11
bandbellandweight30	33.9284	6.83209	11
bandbell30	29.7177	5.22012	11

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
factor1	Pillai's Trace	.694	6.051[b]	3.000	8.000	.019	.694
	Wilks' Lambda	.306	6.051[b]	3.000	8.000	.019	.694
	Hotelling's Trace	2.269	6.051[b]	3.000	8.000	.019	.694
	Roy's Largest Root	2.269	6.051[b]	3.000	8.000	.019	.694

a. Design: Intercept
Within Subjects Design: factor1

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: activation

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]

					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
factor1	.543	5.332	5	.379	.693	.878	.333

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: factor1

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: activation

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
factor1	Sphericity Assumed	160.232	3	53.411	7.084	.001	.415
	Greenhouse-Geisser	160.232	2.078	77.106	7.084	.004	.415
	Huynh-Feldt	160.232	2.633	60.854	7.084	.002	.415
	Lower-bound	160.232	1.000	160.232	7.084	.024	.415
Error(factor1)	Sphericity Assumed	226.200	30	7.540			
	Greenhouse-Geisser	226.200	20.781	10.885			
	Huynh-Feldt	226.200	26.331	8.591			
	Lower-bound	226.200	10.000	22.620			

Tests of Within-Subjects Contrasts

Measure: activation

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
factor1	Linear	40.894	1	40.894	6.944	.025	.410
	Quadratic	2.008	1	2.008	.209	.657	.020

	Cubic	117.330	1	117.330	16.455	.002	.622
Error(factor1)	Linear	58.889	10	5.889			
	Quadratic	96.006	10	9.601			
	Cubic	71.305	10	7.131			

Tests of Between-Subjects Effects

Measure: activation
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	44929.546	1	44929.546	407.093	.000	.976
Error	1103.669	10	110.367			

Estimated Marginal Means

factor1

Estimates

Measure: activation

factor1	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	33.765	1.676	30.032	37.499
2	30.409	1.600	26.843	33.975
3	33.928	2.060	29.339	38.518
4	29.718	1.574	26.211	33.225

Pairwise Comparisons

Measure: activation

(I) factor1		Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	3.356[*]	.868	.019	.513	6.199
	3	-.163	1.007	1.000	-3.462	3.136
	4	4.047[*]	1.171	.037	.212	7.883
2	1	-3.356[*]	.868	.019	-6.199	-.513
	3	-3.519[*]	.998	.033	-6.791	-.248
	4	.691	1.216	1.000	-3.293	4.676
3	1	.163	1.007	1.000	-3.136	3.462
	2	3.519[*]	.998	.033	.248	6.791
	4	4.211	1.617	.158	-1.087	9.508
4	1	-4.047[*]	1.171	.037	-7.883	-.212
	2	-.691	1.216	1.000	-4.676	3.293
	3	-4.211	1.617	.158	-9.508	1.087

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	.694	6.051[a]	3.000	8.000	.019	.694
Wilks' lambda	.306	6.051[a]	3.000	8.000	.019	.694
Hotelling's trace	2.269	6.051[a]	3.000	8.000	.019	.694
Roy's largest root	2.269	6.051[a]	3.000	8.000	.019	.694

Each F tests the multivariate effect of factor1. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

```
T-TEST PAIRS=bar20 bar30 bar40 WITH band20 bandbell30 bandbell40 (PAIRED)
  /CRITERIA=CI(.9500)
  /MISSING=ANALYSIS.
```

Delts

T-Test

Notes

Output Created		28-OCT-2013 19:22:51
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	11
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	Statistics for each analysis are based on the cases with no missing or out-of-range data for any variable in the analysis.

Syntax		T-TEST PAIRS=bar20 bar30 bar40 WITH band20 bandbell30 bandbell40 (PAIRED) /CRITERIA=CI(.9500) /MISSING=ANALYSIS.
Resources	Processor Time	00:00:00.02
	Elapsed Time	00:00:00.01

[DataSet0]

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	bar20	23.9931	11	5.02207	1.51421
	band20	21.4268	11	5.25315	1.58388
Pair 2	bar30	34.1737	11	5.23501	1.57841
	bandbell30	26.7725	11	6.75590	2.03698
Pair 3	bar40	38.9138	11	6.36149	1.91806
	bandbell40	33.9183	11	7.00028	2.11066

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	bar20 & band20	11	.936	.000
Pair 2	bar30 & bandbell30	11	.334	.315
Pair 3	bar40 & bandbell40	11	.330	.322

Paired Samples Test

		Paired Differences					t	df
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference			
					Lower	Upper		
Pair 1	bar20 - band20	2.56638	1.85317	.55875	1.32141	3.81136	4.593	10
Pair 2	bar30 - bandbell30	7.40120	7.02996	2.11961	2.67841	12.12400	3.492	10
Pair 3	bar40 - bandbell40	4.99546	7.75404	2.33793	-.21377	10.20469	2.137	10

```
GLM bar30 barandbands30 bandbellandweight30 bandbell30
  /WSFACTOR=factor1 4 Polynomial
  /MEASURE=activation
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(factor1) COMPARE ADJ(BONFERRONI)
  /PRINT=DESCRIPTIVE ETASQ
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=factor1.
```

General Linear Model

Notes

Output Created		28-OCT-2013 19:24:02
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	11

Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax		GLM bar30 barandbands30 bandbellandweight30 bandbell30 /WSFACTOR=factor1 4 Polynomial /MEASURE=activation /METHOD=SSTYPE(3) /EMMEANS=TABLES(factor1) COMPARE ADJ(BONFERRONI) /PRINT=DESCRIPTIVE ETASQ /CRITERIA=ALPHA(.05) /WSDESIGN=factor1.
Resources	Processor Time	00:00:00.02
	Elapsed Time	00:00:00.03

[DataSet0]

Within-Subjects Factors

Measure: activation

factor1	Dependent Variable

1	bar30
2	barandbands30
3	bandbellandweight30
4	bandbell30

Descriptive Statistics

	Mean	Std. Deviation	N
bar30	34.1737	5.23501	11
barandbands30	30.6929	5.36106	11
bandbellandweight30	29.4294	4.87567	11
bandbell30	26.7725	6.75590	11

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
factor1	Pillai's Trace	.611	4.191[b]	3.000	8.000	.047	.611
	Wilks' Lambda	.389	4.191[b]	3.000	8.000	.047	.611
	Hotelling's Trace	1.572	4.191[b]	3.000	8.000	.047	.611
	Roy's Largest Root	1.572	4.191[b]	3.000	8.000	.047	.611

a. Design: Intercept
Within Subjects Design: factor1

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: activation

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]

					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
factor1	.119	18.601	5	.002	.556	.654	.333

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: factor1

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: activation

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
factor1	Sphericity Assumed	311.925	3	103.975	7.436	.001	.426
	Greenhouse-Geisser	311.925	1.668	186.999	7.436	.007	.426
	Huynh-Feldt	311.925	1.962	158.970	7.436	.004	.426
	Lower-bound	311.925	1.000	311.925	7.436	.021	.426
Error(factor1)	Sphericity Assumed	419.493	30	13.983			
	Greenhouse-Geisser	419.493	16.681	25.149			
	Huynh-Feldt	419.493	19.622	21.379			
	Lower-bound	419.493	10.000	41.949			

Tests of Within-Subjects Contrasts

Measure: activation

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
factor1	Linear	302.887	1	302.887	11.072	.008	.525
	Quadratic	1.867	1	1.867	.163	.695	.016

	Cubic	7.171	1	7.171	2.301	.160	.187
Error(factor1)	Linear	273.558	10	27.356			
	Quadratic	114.776	10	11.478			
	Cubic	31.159	10	3.116			

Tests of Between-Subjects Effects

Measure: activation
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	40308.334	1	40308.334	482.092	.000	.980
Error	836.113	10	83.611			

Estimated Marginal Means

factor1

Estimates

Measure: activation

factor1	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	34.174	1.578	30.657	37.691
2	30.693	1.616	27.091	34.294
3	29.429	1.470	26.154	32.705
4	26.772	2.037	22.234	31.311

Pairwise Comparisons

Measure: activation

(I) factor1		Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	3.481	1.327	.153	-.869	7.830
	3	4.744*	1.211	.017	.777	8.711
	4	7.401*	2.120	.035	.456	14.347
2	1	-3.481	1.327	.153	-7.830	.869
	3	1.263	1.023	1.000	-2.090	4.617
	4	3.920	2.183	.617	-3.234	11.075
3	1	-4.744*	1.211	.017	-8.711	-.777
	2	-1.263	1.023	1.000	-4.617	2.090
	4	2.657	1.311	.421	-1.640	6.953
4	1	-7.401*	2.120	.035	-14.347	-.456
	2	-3.920	2.183	.617	-11.075	3.234
	3	-2.657	1.311	.421	-6.953	1.640

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	.611	4.191[a]	3.000	8.000	.047	.611
Wilks' lambda	.389	4.191[a]	3.000	8.000	.047	.611
Hotelling's trace	1.572	4.191[a]	3.000	8.000	.047	.611
Roy's largest root	1.572	4.191[a]	3.000	8.000	.047	.611

Each F tests the multivariate effect of factor1. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

```
T-TEST PAIRS=bar20 bar30 bar40 WITH band20 bandbell30 bandbell40 (PAIRED)
  /CRITERIA=CI(.9500)
  /MISSING=ANALYSIS.
```

Lats

T-Test

Notes

Output Created		28-OCT-2013 19:25:12
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	11
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	Statistics for each analysis are based on the cases with no missing or out-of-range data for any variable in the analysis.

Syntax		T-TEST PAIRS=bar20 bar30 bar40 WITH band20 bandbell30 bandbell40 (PAIRED) /CRITERIA=CI(.9500) /MISSING=ANALYSIS.
Resources	Processor Time	00:00:00.02
	Elapsed Time	00:00:00.02

[DataSet0]

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	bar20	16.9203	11	6.06241	1.82789
	band20	19.5939	11	6.90269	2.08124
Pair 2	bar30	24.6148	11	10.30178	3.10610
	bandbell30	27.6669	11	7.55797	2.27881
Pair 3	bar40	28.5480	11	10.57559	3.18866
	bandbell40	37.5182	11	8.34278	2.51544

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	bar20 & band20	11	.811	.002
Pair 2	bar30 & bandbell30	11	.649	.031
Pair 3	bar40 & bandbell40	11	.528	.095

Paired Samples Test

		Paired Differences					t	df
					95% Confidence Interval of the Difference			
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper		
Pair 1	bar20 - band20	-2.67356	4.06608	1.22597	-5.40519	.05807	-2.181	10
Pair 2	bar30 - bandbell30	-3.05210	7.88527	2.37750	-8.34950	2.24529	-1.284	10
Pair 3	bar40 - bandbell40	-8.97020	9.39811	2.83364	-15.28393	-2.65646	-3.166	10

```
GLM bar30 barandbands30 bandbellandweight30 bandbell30
  /WSFACTOR=factor1 4 Polynomial
  /MEASURE=activation
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(factor1) COMPARE ADJ(BONFERRONI)
  /PRINT=DESCRIPTIVE ETASQ
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=factor1.
```

General Linear Model

Notes

Output Created		28-OCT-2013 19:25:47
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	11

Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax		GLM bar30 barandbands30 bandbellandweight30 bandbell30 /WSFACTOR=factor1 4 Polynomial /MEASURE=activation /METHOD=SSTYPE(3) /EMMEANS=TABLES(factor1) COMPARE ADJ(BONFERRONI) /PRINT=DESCRIPTIVE ETASQ /CRITERIA=ALPHA(.05) /WSDESIGN=factor1.
Resources	Processor Time	00:00:00.06
	Elapsed Time	00:00:00.06

[DataSet0]

Within-Subjects Factors

Measure: activation

factor1	Dependent Variable

1	bar30
2	barandbands30
3	bandbellandweight30
4	bandbell30

Descriptive Statistics

	Mean	Std. Deviation	N
bar30	24.6148	10.30178	11
barandbands30	20.1581	7.53896	11
bandbellandweight30	21.9051	10.69847	11
bandbell30	27.6669	7.55797	11

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
factor1	Pillai's Trace	.588	3.801[b]	3.000	8.000	.058	.588
	Wilks' Lambda	.412	3.801[b]	3.000	8.000	.058	.588
	Hotelling's Trace	1.425	3.801[b]	3.000	8.000	.058	.588
	Roy's Largest Root	1.425	3.801[b]	3.000	8.000	.058	.588

a. Design: Intercept
Within Subjects Design: factor1

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: activation

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]

					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
factor1	.500	6.054	5	.304	.704	.897	.333

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: factor1

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: activation

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
factor1	Sphericity Assumed	355.177	3	118.392	2.983	.047	.230
	Greenhouse-Geisser	355.177	2.111	168.231	2.983	.070	.230
	Huynh-Feldt	355.177	2.690	132.018	2.983	.054	.230
	Lower-bound	355.177	1.000	355.177	2.983	.115	.230
Error(factor1)	Sphericity Assumed	1190.484	30	39.683			
	Greenhouse-Geisser	1190.484	21.112	56.388			
	Huynh-Feldt	1190.484	26.904	44.250			
	Lower-bound	1190.484	10.000	119.048			

Tests of Within-Subjects Contrasts

Measure: activation

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
factor1	Linear	65.385	1	65.385	2.199	.169	.180
	Quadratic	287.157	1	287.157	4.406	.062	.306

	Cubic	2.635	1	2.635	.109	.748	.011
Error(factor1)	Linear	297.304	10	29.730			
	Quadratic	651.803	10	65.180			
	Cubic	241.377	10	24.138			

Tests of Between-Subjects Effects

Measure: activation
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	24477.650	1	24477.650	113.588	.000	.919
Error	2154.944	10	215.494			

Estimated Marginal Means

factor1

Estimates

Measure: activation

factor1	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	24.615	3.106	17.694	31.536
2	20.158	2.273	15.093	25.223
3	21.905	3.226	14.718	29.092
4	27.667	2.279	22.589	32.744

Pairwise Comparisons

Measure: activation

(I) factor1		Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	4.457	2.633	.728	-4.170	13.084
	3	2.710	3.466	1.000	-8.648	14.068
	4	-3.052	2.377	1.000	-10.843	4.739
2	1	-4.457	2.633	.728	-13.084	4.170
	3	-1.747	2.035	1.000	-8.416	4.922
	4	-7.509*	2.139	.034	-14.517	-.500
3	1	-2.710	3.466	1.000	-14.068	8.648
	2	1.747	2.035	1.000	-4.922	8.416
	4	-5.762	3.159	.589	-16.112	4.588
4	1	3.052	2.377	1.000	-4.739	10.843
	2	7.509*	2.139	.034	.500	14.517
	3	5.762	3.159	.589	-4.588	16.112

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	.588	3.801[a]	3.000	8.000	.058	.588
Wilks' lambda	.412	3.801[a]	3.000	8.000	.058	.588
Hotelling's trace	1.425	3.801[a]	3.000	8.000	.058	.588
Roy's largest root	1.425	3.801[a]	3.000	8.000	.058	.588

Each F tests the multivariate effect of factor1. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

```
T-TEST PAIRS=bar20 bar30 bar40 WITH band20 bandbell30 bandbell40 (PAIRED)
  /CRITERIA=CI(.9500)
  /MISSING=ANALYSIS.
```

Obliques

T-Test

Notes

Output Created		28-OCT-2013 19:26:55
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	11
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	Statistics for each analysis are based on the cases with no missing or out-of-range data for any variable in the analysis.

Syntax		T-TEST PAIRS=bar20 bar30 bar40 WITH band20 bandbell30 bandbell40 (PAIRED) /CRITERIA=CI(.9500) /MISSING=ANALYSIS.
Resources	Processor Time	00:00:00.02
	Elapsed Time	00:00:00.01

[DataSet0]

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	bar20	18.5635	11	6.18516	1.86489
	band20	22.8453	11	9.23352	2.78401
Pair 2	bar30	25.7062	11	9.17960	2.76775
	bandbell30	33.6637	11	13.72108	4.13706
Pair 3	bar40	27.8529	11	9.04449	2.72702
	bandbell40	38.1207	11	7.76340	2.34075

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	bar20 & band20	11	.712	.014
Pair 2	bar30 & bandbell30	11	.567	.069
Pair 3	bar40 & bandbell40	11	.801	.003

Paired Samples Test

		Paired Differences					t	df
					95% Confidence Interval of the Difference			
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper		
Pair 1	bar20 - band20	-4.28179	6.49161	1.95729	-8.64291	.07933	-2.188	10
Pair 2	bar30 - bandbell30	-7.95750	11.39218	3.43487	-15.61087	-.30413	-2.317	10
Pair 3	bar40 - bandbell40	-10.26779	5.44105	1.64054	-13.92313	-6.61244	-6.259	10

```
GLM bar30 barandbands30 bandbellandweight30 bandbell30
  /WSFACTOR=factor1 4 Polynomial
  /MEASURE=activation
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(factor1) COMPARE ADJ(BONFERRONI)
  /PRINT=DESCRIPTIVE ETASQ
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=factor1.
```

General Linear Model

Notes

Output Created		28-OCT-2013 19:27:37
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	11

Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax		GLM bar30 barandbands30 bandbellandweight30 bandbell30 /WSFACTOR=factor1 4 Polynomial /MEASURE=activation /METHOD=SSTYPE(3) /EMMEANS=TABLES(factor1) COMPARE ADJ(BONFERRONI) /PRINT=DESCRIPTIVE ETASQ /CRITERIA=ALPHA(.05) /WSDESIGN=factor1.
Resources	Processor Time	00:00:00.06
	Elapsed Time	00:00:00.08

[DataSet0]

Within-Subjects Factors

Measure: activation

factor1	Dependent Variable

1	bar30
2	barandbands30
3	bandbellandweight30
4	bandbell30

Descriptive Statistics

	Mean	Std. Deviation	N
bar30	25.7062	9.17960	11
barandbands30	23.8661	8.33111	11
bandbellandweight30	25.1382	10.54934	11
bandbell30	33.6637	13.72108	11

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
factor1	Pillai's Trace	.670	5.403[b]	3.000	8.000	.025	.670
	Wilks' Lambda	.330	5.403[b]	3.000	8.000	.025	.670
	Hotelling's Trace	2.026	5.403[b]	3.000	8.000	.025	.670
	Roy's Largest Root	2.026	5.403[b]	3.000	8.000	.025	.670

a. Design: Intercept
Within Subjects Design: factor1

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: activation

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]

					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
factor1	.176	15.130	5	.010	.610	.740	.333

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: factor1

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: activation

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
factor1	Sphericity Assumed	652.651	3	217.550	6.473	.002	.393
	Greenhouse-Geisser	652.651	1.830	356.709	6.473	.009	.393
	Huynh-Feldt	652.651	2.219	294.183	6.473	.005	.393
	Lower-bound	652.651	1.000	652.651	6.473	.029	.393
Error(factor1)	Sphericity Assumed	1008.313	30	33.610			
	Greenhouse-Geisser	1008.313	18.296	55.110			
	Huynh-Feldt	1008.313	22.185	45.450			
	Lower-bound	1008.313	10.000	100.831			

Tests of Within-Subjects Contrasts

Measure: activation

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
factor1	Linear	347.740	1	347.740	5.487	.041	.354
	Quadratic	295.480	1	295.480	9.390	.012	.484

	Cubic	9.431	1	9.431	1.574	.238	.136
Error(factor1)	Linear	633.732	10	63.373			
	Quadratic	314.667	10	31.467			
	Cubic	59.914	10	5.991			

Tests of Between-Subjects Effects

Measure: activation
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	32298.717	1	32298.717	91.654	.000	.902
Error	3523.978	10	352.398			

Estimated Marginal Means

factor1

Estimates

Measure: activation

factor1	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	25.706	2.768	19.539	31.873
2	23.866	2.512	18.269	29.463
3	25.138	3.181	18.051	32.225
4	33.664	4.137	24.446	42.882

Pairwise Comparisons

Measure: activation

(I) factor1		Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	1.840	2.490	1.000	-6.318	9.998
	3	.568	2.899	1.000	-8.933	10.069
	4	-7.958	3.435	.258	-19.213	3.298
2	1	-1.840	2.490	1.000	-9.998	6.318
	3	-1.272	.902	1.000	-4.228	1.683
	4	-9.798*	2.234	.008	-17.119	-2.476
3	1	-.568	2.899	1.000	-10.069	8.933
	2	1.272	.902	1.000	-1.683	4.228
	4	-8.526*	2.112	.014	-15.445	-1.606
4	1	7.958	3.435	.258	-3.298	19.213
	2	9.798*	2.234	.008	2.476	17.119
	3	8.526*	2.112	.014	1.606	15.445

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	.670	5.403[a]	3.000	8.000	.025	.670
Wilks' lambda	.330	5.403[a]	3.000	8.000	.025	.670
Hotelling's trace	2.026	5.403[a]	3.000	8.000	.025	.670
Roy's largest root	2.026	5.403[a]	3.000	8.000	.025	.670

Each F tests the multivariate effect of factor1. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

```
T-TEST PAIRS=bar20 bar30 bar40 WITH band20 bandbell30 bandbell40 (PAIRED)
  /CRITERIA=CI(.9500)
  /MISSING=ANALYSIS.
```

VastLat

T-Test

Notes

Output Created		28-OCT-2013 19:28:38
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	11
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	Statistics for each analysis are based on the cases with no missing or out-of-range data for any variable in the analysis.

Syntax		T-TEST PAIRS=bar20 bar30 bar40 WITH band20 bandbell30 bandbell40 (PAIRED) /CRITERIA=CI(.9500) /MISSING=ANALYSIS.
Resources	Processor Time	00:00:00.02
	Elapsed Time	00:00:00.01

```
[DataSet0]
```

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	bar20	22.2710	11	21.89163	6.60057
	band20	23.1551	11	11.80738	3.56006
Pair 2	bar30	19.6551	11	15.46612	4.66321
	bandbell30	31.3235	11	19.10612	5.76071
Pair 3	bar40	31.0400	11	22.39934	6.75365
	bandbell40	36.4191	11	12.76189	3.84786

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	bar20 & band20	11	.345	.299
Pair 2	bar30 & bandbell30	11	.160	.639
Pair 3	bar40 & bandbell40	11	.633	.037

Paired Samples Test

		Paired Differences					t	df
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference			
					Lower	Upper		
Pair 1	bar20 - band20	-.88410	20.98434	6.32702	-14.98157	13.21337	-.140	10
Pair 2	bar30 - bandbell30	-11.66848	22.57994	6.80811	-26.83789	3.50093	-1.714	10
Pair 3	bar40 - bandbell40	-5.37909	17.40278	5.24714	-17.07044	6.31226	-1.025	10

```
GLM bar30 barandbands30 bandbellandweight30 bandbell30
  /WSFACTOR=factor1 4 Polynomial
  /MEASURE=activation
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(factor1) COMPARE ADJ(BONFERRONI)
  /PRINT=DESCRIPTIVE ETASQ
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=factor1.
```

General Linear Model

Notes

Output Created		28-OCT-2013 19:28:48
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	11

Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax		GLM bar30 barandbands30 bandbellandweight30 bandbell30 /WSFACTOR=factor1 4 Polynomial /MEASURE=activation /METHOD=SSTYPE(3) /EMMEANS=TABLES(factor1) COMPARE ADJ(BONFERRONI) /PRINT=DESCRIPTIVE ETASQ /CRITERIA=ALPHA(.05) /WSDESIGN=factor1.
Resources	Processor Time	00:00:00.02
	Elapsed Time	00:00:00.15

[DataSet0]

Within-Subjects Factors

Measure: activation

factor1	Dependent Variable

1	bar30
2	barandbands30
3	bandbellandweight30
4	bandbell30

Descriptive Statistics

	Mean	Std. Deviation	N
bar30	19.6551	15.46612	11
barandbands30	15.9721	9.21753	11
bandbellandweight30	14.0338	10.45328	11
bandbell30	31.3235	19.10612	11

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
factor1	Pillai's Trace	.624	4.419[b]	3.000	8.000	.041	.624
	Wilks' Lambda	.376	4.419[b]	3.000	8.000	.041	.624
	Hotelling's Trace	1.657	4.419[b]	3.000	8.000	.041	.624
	Roy's Largest Root	1.657	4.419[b]	3.000	8.000	.041	.624

a. Design: Intercept
Within Subjects Design: factor1

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: activation

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]

					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
factor1	.116	18.820	5	.002	.537	.625	.333

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: factor1

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: activation

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
factor1	Sphericity Assumed	1979.110	3	659.703	5.164	.005	.341
	Greenhouse-Geisser	1979.110	1.612	1227.607	5.164	.024	.341
	Huynh-Feldt	1979.110	1.876	1055.077	5.164	.018	.341
	Lower-bound	1979.110	1.000	1979.110	5.164	.046	.341
Error(factor1)	Sphericity Assumed	3832.369	30	127.746			
	Greenhouse-Geisser	3832.369	16.122	237.715			
	Huynh-Feldt	3832.369	18.758	204.306			
	Lower-bound	3832.369	10.000	383.237			

Tests of Within-Subjects Contrasts

Measure: activation

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
factor1	Linear	601.388	1	601.388	2.681	.133	.211
	Quadratic	1209.602	1	1209.602	10.534	.009	.513

	Cubic	168.120	1	168.120	3.814	.079	.276
Error(factor1)	Linear	2243.286	10	224.329			
	Quadratic	1148.239	10	114.824			
	Cubic	440.844	10	44.084			

Tests of Between-Subjects Effects

Measure: activation
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	18035.841	1	18035.841	43.435	.000	.813
Error	4152.416	10	415.242			

Estimated Marginal Means

factor1

Estimates

Measure: activation

factor1	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	19.655	4.663	9.265	30.045
2	15.972	2.779	9.780	22.165
3	14.034	3.152	7.011	21.056
4	31.324	5.761	18.488	44.159

Pairwise Comparisons

Measure: activation

(I) factor1		Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	3.683	3.890	1.000	-9.063	16.429
	3	5.621	3.170	.640	-4.766	16.009
	4	-11.668	6.808	.704	-33.978	10.641
2	1	-3.683	3.890	1.000	-16.429	9.063
	3	1.938	1.566	1.000	-3.193	7.070
	4	-15.351	5.768	.143	-34.253	3.550
3	1	-5.621	3.170	.640	-16.009	4.766
	2	-1.938	1.566	1.000	-7.070	3.193
	4	-17.290	5.666	.073	-35.856	1.277
4	1	11.668	6.808	.704	-10.641	33.978
	2	15.351	5.768	.143	-3.550	34.253
	3	17.290	5.666	.073	-1.277	35.856

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	.624	4.419[a]	3.000	8.000	.041	.624
Wilks' lambda	.376	4.419[a]	3.000	8.000	.041	.624
Hotelling's trace	1.657	4.419[a]	3.000	8.000	.041	.624
Roy's largest root	1.657	4.419[a]	3.000	8.000	.041	.624

Each F tests the multivariate effect of factor1. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

```
T-TEST PAIRS=bar20 bar30 bar40 WITH band20 bandbell30 bandbell40 (PAIRED)
  /CRITERIA=CI(.9500)
  /MISSING=ANALYSIS.
```

Gastroc

T-Test

Notes

Output Created		28-OCT-2013 19:29:35
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	11
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	Statistics for each analysis are based on the cases with no missing or out-of-range data for any variable in the analysis.

Syntax		T-TEST PAIRS=bar20 bar30 bar40 WITH band20 bandbell30 bandbell40 (PAIRED) /CRITERIA=CI(.9500) /MISSING=ANALYSIS.
Resources	Processor Time	00:00:00.02
	Elapsed Time	00:00:00.01

[DataSet0]

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	bar20	16.2096	11	12.86459	3.87882
	band20	14.1969	11	9.85732	2.97209
Pair 2	bar30	16.6553	11	13.43046	4.04944
	bandbell30	26.3681	11	24.37283	7.34868
Pair 3	bar40	14.4761	11	11.86615	3.57778
	bandbell40	28.8540	11	15.20889	4.58565

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	bar20 & band20	11	.651	.030
Pair 2	bar30 & bandbell30	11	-.062	.856
Pair 3	bar40 & bandbell40	11	-.371	.261

Paired Samples Test

		Paired Differences					t	df
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper		
Pair 1	bar20 - band20	2.01272	9.87196	2.97651	-4.61935	8.64479	.676	10
Pair 2	bar30 - bandbell30	-9.71280	28.55199	8.60875	-28.89429	9.46869	-1.128	10
Pair 3	bar40 - bandbell40	-14.37784	22.49575	6.78272	-29.49069	.73501	-2.120	10

```
GLM bar30 barandbands30 bandbellandweight30 bandbell30
  /WSFACTOR=factor1 4 Polynomial
  /MEASURE=activation
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(factor1) COMPARE ADJ(BONFERRONI)
  /PRINT=DESCRIPTIVE ETASQ
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=factor1.
```

General Linear Model

Notes

Output Created		28-OCT-2013 19:30:18
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	11

Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax		GLM bar30 barandbands30 bandbellandweight30 bandbell30 /WSFACTOR=factor1 4 Polynomial /MEASURE=activation /METHOD=SSTYPE(3) /EMMEANS=TABLES(factor1) COMPARE ADJ(BONFERRONI) /PRINT=DESCRIPTIVE ETASQ /CRITERIA=ALPHA(.05) /WSDESIGN=factor1.
Resources	Processor Time	00:00:00.03
	Elapsed Time	00:00:00.05

```
[DataSet0]
```

Within-Subjects Factors

Measure: activation

factor1	Dependent Variable

1	bar30
2	barandbands30
3	bandbellandweight30
4	bandbell30

Descriptive Statistics

	Mean	Std. Deviation	N
bar30	16.6553	13.43046	11
barandbands30	13.4745	10.85095	11
bandbellandweight30	9.2645	7.34890	11
bandbell30	26.3681	24.37283	11

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
factor1	Pillai's Trace	.685	5.791[b]	3.000	8.000	.021	.685
	Wilks' Lambda	.315	5.791[b]	3.000	8.000	.021	.685
	Hotelling's Trace	2.172	5.791[b]	3.000	8.000	.021	.685
	Roy's Largest Root	2.172	5.791[b]	3.000	8.000	.021	.685

a. Design: Intercept
Within Subjects Design: factor1

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: activation

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]

					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
factor1	.109	19.364	5	.002	.526	.607	.333

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: factor1

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: activation

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
factor1	Sphericity Assumed	1747.849	3	582.616	2.544	.075	.203
	Greenhouse-Geisser	1747.849	1.577	1108.330	2.544	.119	.203
	Huynh-Feldt	1747.849	1.822	959.275	2.544	.110	.203
	Lower-bound	1747.849	1.000	1747.849	2.544	.142	.203
Error(factor1)	Sphericity Assumed	6869.229	30	228.974			
	Greenhouse-Geisser	6869.229	15.770	435.585			
	Huynh-Feldt	6869.229	18.221	377.005			
	Lower-bound	6869.229	10.000	686.923			

Tests of Within-Subjects Contrasts

Measure: activation

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
factor1	Linear	341.783	1	341.783	.924	.359	.085
	Quadratic	1131.504	1	1131.504	4.836	.053	.326

	Cubic	274.562	1	274.562	3.302	.099	.248
Error(factor1)	Linear	3697.764	10	369.776			
	Quadratic	2339.976	10	233.998			
	Cubic	831.489	10	83.149			

Tests of Between-Subjects Effects

Measure: activation
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	11892.884	1	11892.884	45.876	.000	.821
Error	2592.386	10	259.239			

Estimated Marginal Means

factor1

Estimates

Measure: activation

factor1	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	16.655	4.049	7.633	25.678
2	13.475	3.272	6.185	20.764
3	9.264	2.216	4.327	14.202
4	26.368	7.349	9.994	42.742

Pairwise Comparisons

Measure: activation

(I) factor1		Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	3.181	5.064	1.000	-13.412	19.773
	3	7.391	3.188	.257	-3.057	17.838
	4	-9.713	8.609	1.000	-37.922	18.497
2	1	-3.181	5.064	1.000	-19.773	13.412
	3	4.210	2.870	1.000	-5.196	13.616
	4	-12.894	8.548	.974	-40.904	15.117
3	1	-7.391	3.188	.257	-17.838	3.057
	2	-4.210	2.870	1.000	-13.616	5.196
	4	-17.104	7.653	.297	-42.181	7.973
4	1	9.713	8.609	1.000	-18.497	37.922
	2	12.894	8.548	.974	-15.117	40.904
	3	17.104	7.653	.297	-7.973	42.181

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	.685	5.791[a]	3.000	8.000	.021	.685
Wilks' lambda	.315	5.791[a]	3.000	8.000	.021	.685
Hotelling's trace	2.172	5.791[a]	3.000	8.000	.021	.685
Roy's largest root	2.172	5.791[a]	3.000	8.000	.021	.685

Each F tests the multivariate effect of factor1. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic